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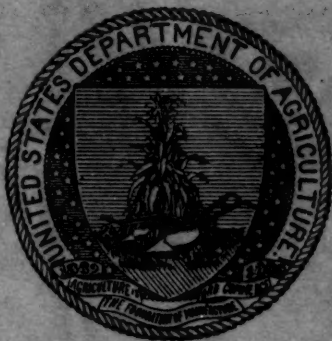
U. S. DEPARTMENT OF AGRICULTURE  
WEATHER BUREAU  
CHARLES F. MARVIN, Chief

U.S.

# MONTHLY WEATHER REVIEW

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The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of contributions is not to be construed as official approval of the views expressed.

#### ECONOMIES IN PRINTING.

Contributions intended for publication in the REVIEW must in all cases conform to the regulations of the Department of Agriculture with respect to effecting economies in the public printing. The following memorandum in regard to preparing manuscripts for publication has just been issued by the Department.

It is reproduced below for the information of all concerned.

Authors will be expected to prepare their manuscripts, with the understanding that once the manuscript leaves the author's hands it is in final form and not subject to further changes of text in galley or page proof. With the adoption of this policy it will be necessary that authors consult workers on related subjects in other Bureaus before finally submitting their manuscript for publication, and all matters as to which there is difference of opinion must be settled in advance.

#### BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. An addressed franked slip may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.

1915: May, June, July, August.

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1918: February, September.

1919: Any issue, especially November.

1920: Any issue, especially January.

SUPPLEMENT, No. 3.

# MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

VOL. 49, No. 9.  
W. B. No. 753.

SEPTEMBER, 1921.

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ISSUED DEC. 1, 1921

## SKY-BRIGHTNESS AND DAYLIGHT-ILLUMINATION MEASUREMENTS.\*

By HERBERT H. KIMBALL and IRVING F. HAND.

[Weather Bureau, Washington, Sept. 30, 1921.]

### SYNOPSIS.

The brightness of the sky was measured almost daily at the American University, Washington, D. C., between April 5 and July 14, inclusive, and at Chicago, Ill., between July 19 and August 13, inclusive, 1921.

The illumination from sunlight and skylight combined, and from skylight alone, was measured on a horizontal surface, and also on a surface normal to the incident solar rays; and at Washington, in addition, measurements were made of the skylight illumination on vertical surfaces facing 0°, 45°, 90°, 135°, and 180° in azimuth from the sun.

The measurements were made with a Sharp-Millar photometer, the constants of which have been checked frequently at the United States Bureau of Standards.

About half the Chicago measurements were made on top of the dome of the Federal Building, in the Loop district, one of the smokiest sections of the city. The remainder were made at the University of Chicago, which in summer is comparatively free from smoke when the wind blows from the lake. Southeast and southwest winds, however, bring considerable smoke from South Chicago and the Union Stockyards, respectively.

There is little smoke in the atmosphere at the American University, D. C.

A comparison of the Washington and Chicago measurements shows that toward the sun on cloudless days the sky brightness does not differ materially at the two places, but opposite the sun the horizon in Chicago is darkened by the smoke, especially in the Loop district.

With a cloudless sky the direct solar illumination at Chicago is noticeably weaker than at Washington, and in the Loop district, with the sun not more than 40° above the horizon, it averages only 80 per cent as intense. The illumination on a vertical surface facing 180° in azimuth from the sun, computed from the sky-brightness measurements, averages only about two-thirds as intense as the illumination computed from similar measurements for Washington.

### PHOTOMETRIC UNITS.

In photometric measurements, as in all others, a unit of measure is required. In the United States the International candle is the unit generally employed.

For the purpose of this paper three definitions become necessary, as follows:

(1) *Luminous flux*,  $= F$ , = radiant power evaluated according to visibility, i. e., capacity to produce the sensation of light. The flux emitted in a unit solid angle by a point source of one candle power = one lumen.

(2) *The illumination on a surface*, = flux density on the surface,  $= F/S$ , where  $S$  is the area of the surface. Thus, a flux of one lumen has a surface density of a foot-candle at a distance of one foot, a meter-candle at a distance of one meter, and a phot at a distance of one centimeter. There are 30.48 centimeters in one foot; therefore one phot = 929 foot-candles, since  $(30.48)^2 = 929$ .

(3) *The brightness of a perfectly-diffusing surface* radiating or reflecting one lumen per square centimeter is one lambert. It is equivalent to a perfectly-diffusing surface with an illumination of one phot.

### OBSERVATIONAL PROGRAM.

*Sky brightness.*—The source of the brightness of the sky is threefold: (1) The direct diffusion of sunlight by

the gas molecules and dust and other particles in the atmosphere; (2) reflection of light from the surface of the ground and other objects; (3) secondary diffusion of light by the atmosphere. The diameters of gas molecules are small as compared with the wave length of light and cause a greater proportion of scattering at the blue end of the spectrum than at the red end, giving the sky its blue color. The diameters of the dust and other particles in the atmosphere are generally large as compared with the wave length of light. These particles therefore reflect the white light from the sun, and greatly dilute the blue color of the sky.

When detached clouds are present they reflect a variable percentage of the light that they receive, depending upon both the angle of incidence and the angle of reflection of the light. If the cloud layer is continuous, and everywhere of equal thickness and density, it approaches a matt surface, and its underside should be everywhere of equal brightness.

From the laws of diffusion or scattering and of the reflection of light, it follows that the brightness of the sky should be symmetrical on the two sides of a vertical circle through the observer and the sun, unless the cloud or haze distribution is unsymmetrical, or the surface of the earth under the two sides differs materially, as for instance, land under one side and water under the other. In order to economize the time required for making the measurements, it has been assumed that the sky brightness is symmetrical on the two sides of the sun's vertical. Measurements are therefore confined to one side, and it is generally a matter of chance on which side they are made.

The observational program calls for a series of measurements as nearly as possible when the altitude of the sun above the horizon is 0°, 20°, 40°, 60°, and 70°. Not many observations are obtained in summer with solar altitudes 0° and 20°, and none can be obtained in winter with solar altitudes 60° and 70°. A complete series of readings includes measurements at 2°, 15°, 30°, 45°, 60°, 75°, and 90° above the horizon on vertical quadrants of circles at 0°, 45°, 90°, 135° and 180° of azimuth from the sun's vertical. Three photometric settings are made at each point, or 105 settings for each series, which latter generally requires from 10 to 12 minutes of time.

For the purpose of classifying the observations they have been grouped according to the solar altitude at the time of the measurements and the state of the sky. Skies have been classified as follows: (1) clear, when few or no clouds are present in the half of the sky measured; (2) overcast with thin clouds or dense haze; (3) completely covered with clouds or dense fog, so that neither the sun nor blue sky can be seen; (4) covered with clouds from which rain or snow is falling; and (5) partly overcast with clouds. This latter includes all that can not be included in the first four classifications.

*Illumination.*—At Washington, with a clear sky, the total daylight illumination (solar + sky) is measured on a

\* Condensed from the Report of the Committee on Sky Brightness, Illuminating Engineering Society, as presented at the Annual Convention, Rochester, N. Y., Sept. 28 to 29, 1921, by Herbert H. Kimball, Chairman of the committee. Published in Transactions of Illuminating Engineering Society, Oct. 10, 1921.

horizontal surface and on a surface normal to the incident solar rays, and the skylight illumination on the same surfaces and also on vertical surfaces facing  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ , and  $180^\circ$ , in azimuth from the sun. With a cloudy sky the skylight illumination is measured on a horizontal surface, and on vertical surfaces oriented as above, the sun's azimuth being calculated approximately.

At Chicago, measurements were made of the total daylight illumination, and of the skylight illumination alone, on a horizontal surface, and also on a surface normal to the incident solar rays, when no clouds were present. With a cloudy sky the skylight illumination was measured on a horizontal surface only.

A compensated test plate was employed in all illumination measurements. The certificate furnished by the Electrical Testing Laboratories, New York, shows that the deviation of the measured brightness of the plate from the theoretical brightness, according to Lambert's cosine law, is less than 1 per cent for all angles of incidence up to and including  $40^\circ$ , and is only -2 per cent at  $80^\circ$ .

Figure 1 shows the photometer mounted in its shelter on the roof of the College of History, American University, D. C. The sides of the shelter rise to the level of the center of the test plate when the elbow tube of the photometer is horizontal. The inside of the shelter is painted flat black, and measurements indicate that its coefficient of reflection is only about 3 per cent. This greatly reduces the reflection of light to the test plate from objects below it.

Resting on the photometer is a shade that is used to shield the test plate from direct sunlight when desired.

#### SUMMARY OF SKY BRIGHTNESS MEASUREMENTS.

A summary of these measurements can best be shown by graphic methods, as in figures 2 and 3. Half the sky on one side of the sun's vertical is shown in stereographic projection in Figure 2 (a) to (h), inclusive, and Figure 3, (a), (b), (c), and (e). Figure 3, (d) and (f), are for the half of the sky farthest from the sun. The figures at one end of the lines of equal sky brightness give the brightness relative to the zenith. At the other end, they give the brightness in millilamberts.

The data for Washington represent the means of measurements obtained on about 25 clear half days, 29 cloudy half days, and 15 half days with the sky covered with thin clouds or haze. Those for Chicago represent about seven clear half days and only one cloudy day.

Figure 2, (a), (b), and (e), for Washington, show the change that occurs in the brightness of a clear sky with increase in solar altitude. In general, there is a point of minimum brightness a little less than  $90^\circ$  from the sun and in his vertical, and a dark valley extends from this point to a point between the sun and the horizon. The brightest area is about the sun, and the brightness generally increases from the zenith towards the horizon. These charts are in good accord with those constructed by Dorno<sup>1</sup> from measurements made at Davos, Switzerland, except that the horizon, and the sky opposite the sun, is in general brighter at Davos than at Washington, especially in winter, probably because of the greater amount of light reflected to the sky by the snow-covered Alps. Some unpublished measurements made by F. W. Little at Key West and Sand Keys, Fla., and off Long Island, N. Y., give a darker horizon opposite the sun than

is given by the Washington data, probably because most of Little's measurements were made over a water surface, which is a poor reflector of light. Dorno<sup>2</sup> found the albedo of a snow surface to be from 60 per cent to 74 per cent, the latter for newly fallen snow, as compared with 6 to 7 per cent for grass-covered ground, and 2 per cent for a water surface. He also found that with the sun  $30^\circ$  above the horizon its surface brightness is 1,000,000 times the brightness of the clear sky in the zenith.<sup>3</sup>

A comparison of figure 2, (c) and (d), for Chicago with figure 2, (b), for Washington shows marked similarity, except that at Chicago the horizon opposite the sun is darker than at Washington. This is especially the case in the "Loop" district, where, at azimuth  $135^\circ$  from the sun, the measurements show the horizon to be less than half as bright as at Washington.

The data of figure 2, (f), for Washington and (g) and (h) for Chicago, with a cloudy sky, show a radical departure from the data for cloudless skies. The brightest area is near the zenith, from which there is a nearly uniform decrease in brightness in all directions to the horizon. In the "Loop" district of Chicago the horizon is again less than half as bright as the horizon at Washington.

This darkening of the horizon can not be attributed to the influence of Lake Michigan, since with a clear sky it is quite as marked in the morning, when the photometer tube is pointed away from the lake, as in the afternoon, when the tube is pointed toward the lake. It must be attributed to the smoke cloud, which is dark in color in comparison with either the clear sky or cloud surfaces.

Mention should here be made of a series of measurements of the brightness of the sky in the zenith made at Chicago between October, 1897, and August, 1899,<sup>4</sup> which gives for the annual mean zenithal brightness at noon, expressed in candles per square foot, for a cloudy sky 200 candles; a clear sky, 305 candles; and a sky covered with thin clouds, 620 candles. Expressed in millilamberts, these become 676, 1031, and 2096, respectively. The two latter values approximate the brightness of the sky at Washington under like conditions with respect to clouds, when the sun is  $40^\circ$  above the horizon. The value for a cloudy sky is about that for a sky in Washington covered with clouds from which rain is falling with the sun  $20^\circ$  above the horizon.

The monthly mean values with a clear sky are higher than measurements at Washington with the sun at corresponding altitudes above the horizon, while the monthly means for a cloudy sky are markedly lower, especially during the fall and winter months.

The data of figure 3, (a), shows that at Washington thin clouds or dense haze increase the brightness of the sky, especially in the zenith and near the sun. This is the brightest type of sky measured at Washington.

With rain falling the brightness distribution is much the same as with a cloud or fog-covered sky, but the absolute brightness averages only about half as great.

With the sky partly covered with clouds the brightness varies from that of a clear sky to that with a sky covered with thin clouds or dense haze. Luckiesh<sup>5</sup> and Aldrich,<sup>6</sup> working independently, have found that dense

<sup>1</sup> Loc. cit., p. 214.

<sup>2</sup> Loc. cit., Table 14.

<sup>3</sup> Basquin, O. H. Daylight Illumination. II. Brightness of the Sky. *The Illuminating Engineer*, New York, Dec., 1906. Vol. 1, pp. 823-829.

<sup>4</sup> Luckiesh, M. The Visibility of Air Planes. *Jr. Franklin Institute*, 1919, vol. 187, p. 306.

<sup>5</sup> Aldrich, L. B. The Reflecting Power of Clouds. *Smithsonian Misc. Coll.*, vol. 69, No. 10.

<sup>6</sup> Dorno, C. Himmelselligkeit, Himmelspolarisation und Sonnenintensität in Davos 1911 bis 1913. *Veröffentlichungen des Preussischen Meteorologischen Instituts*, Nr. 303. Abhandlungen Bd. VI.

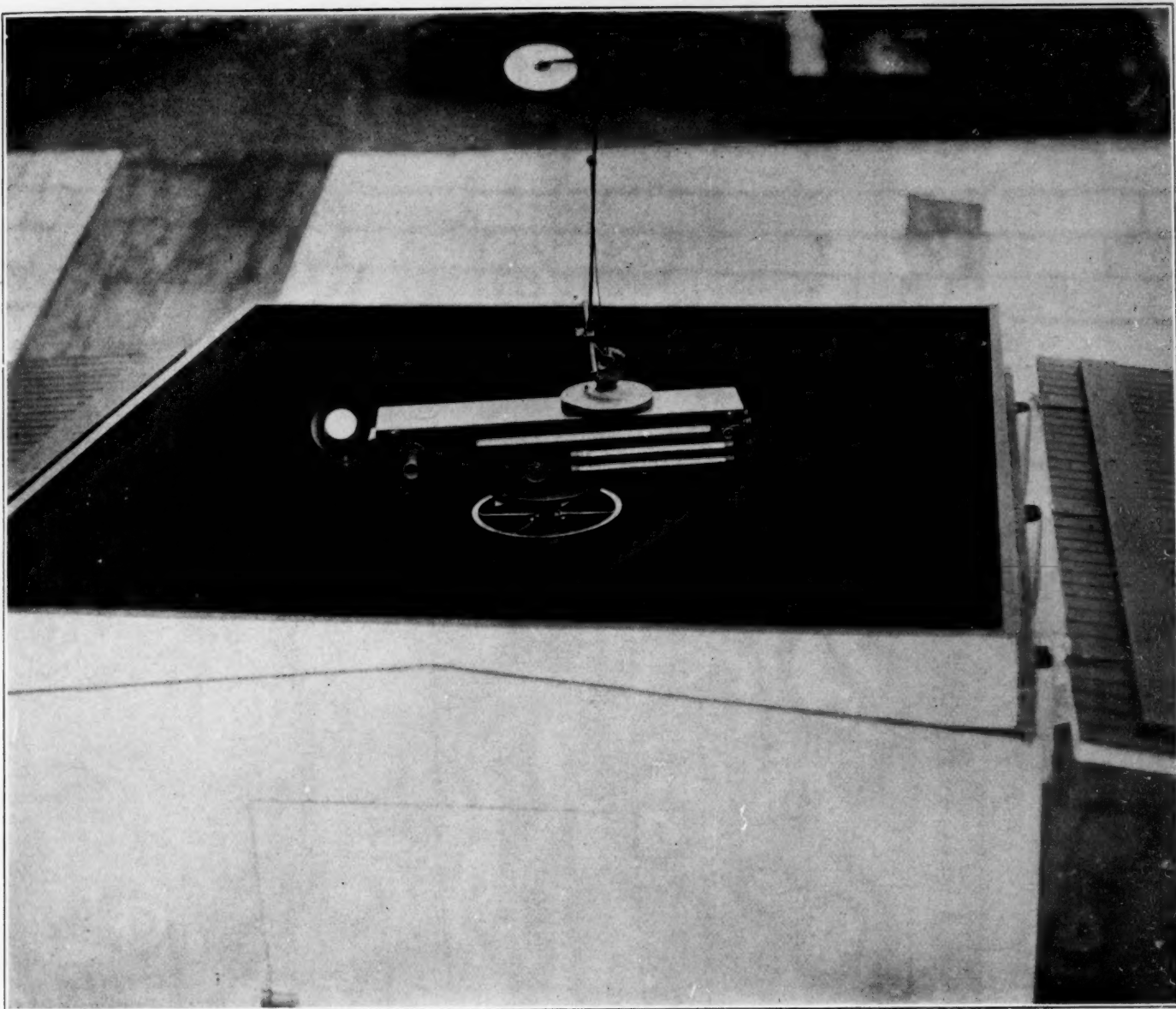
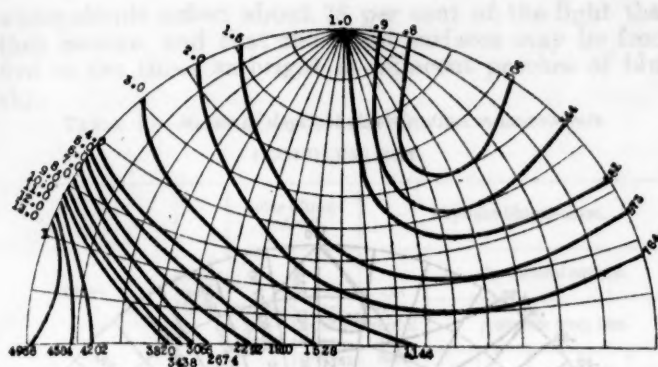
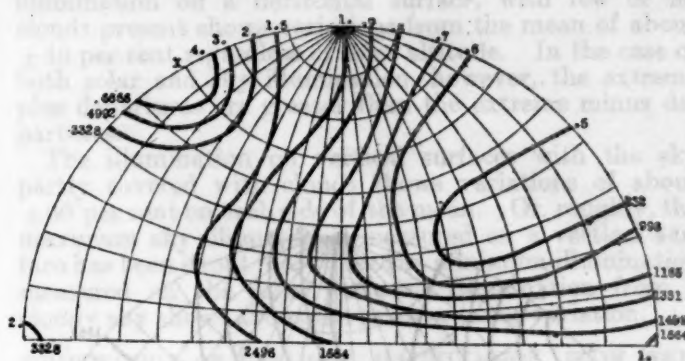


FIG. 1.—Photometer and shelter.

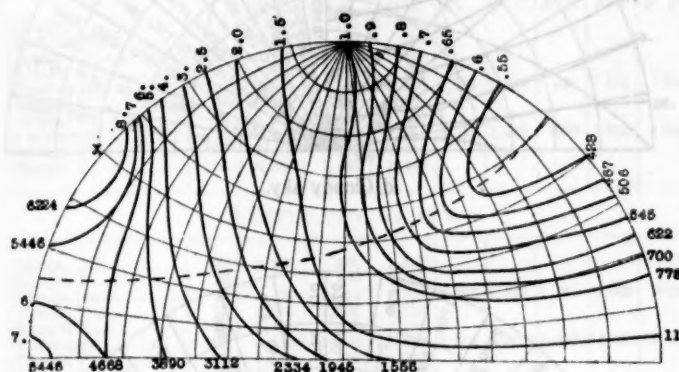




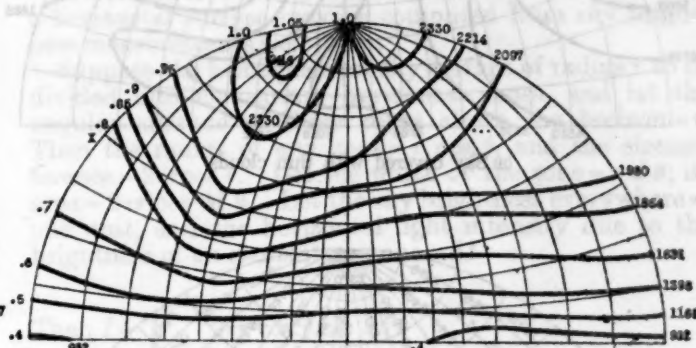
(a) Washington, D. C. Clear sky.



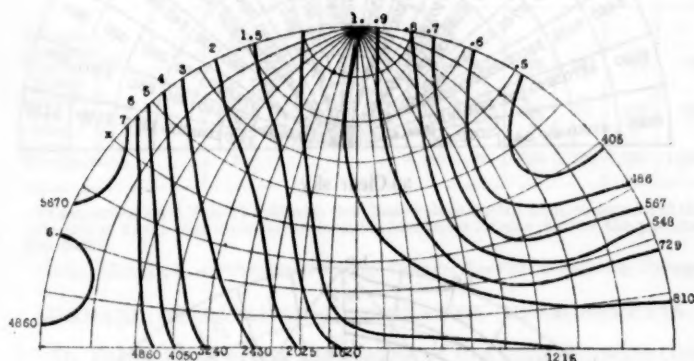
(c) Washington, D. C. Clear sky.



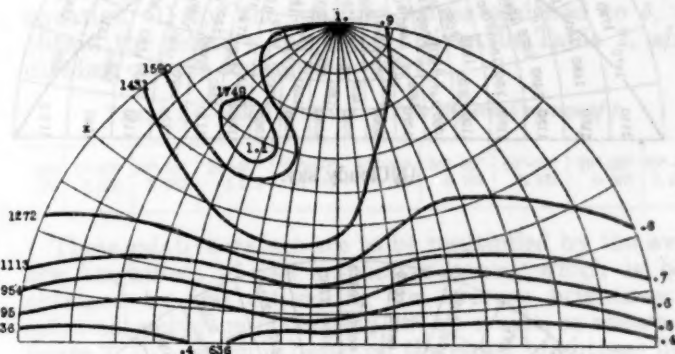
(b) Washington, D. C. Clear sky.



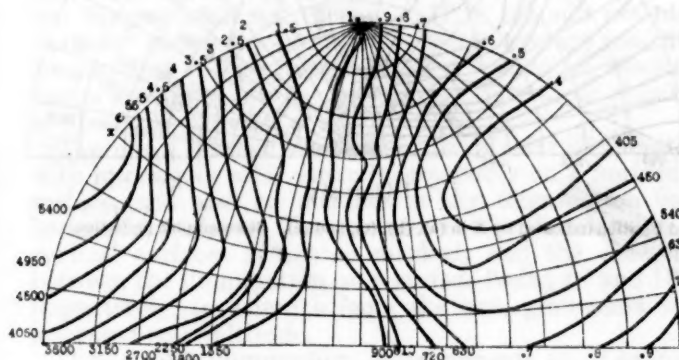
(f) Washington, D. C. Cloudy sky.



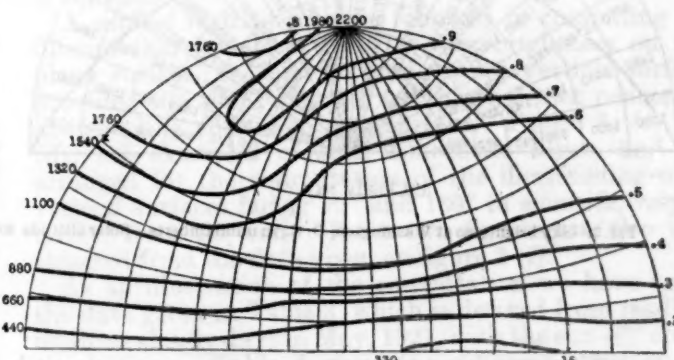
(c) University of Chicago. Clear sky.



(g) University of Chicago. Cloudy sky.

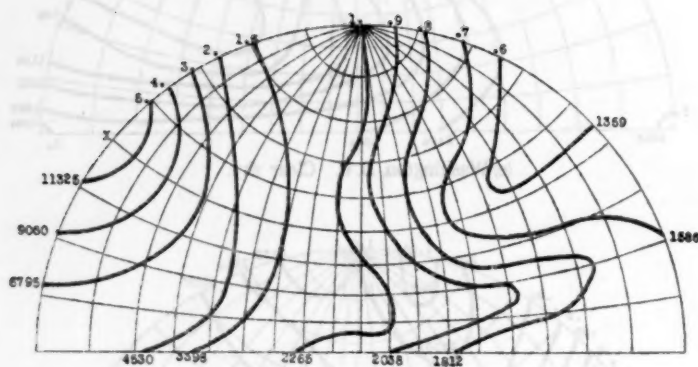


(d) Federal Building, Chicago, Ill. Clear sky.

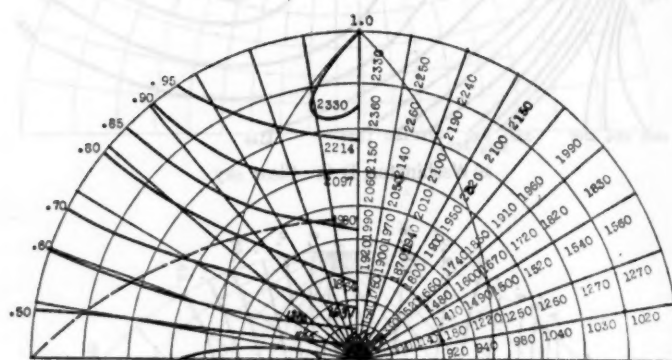


(h) Federal Building, Chicago, Ill. Cloudy sky.

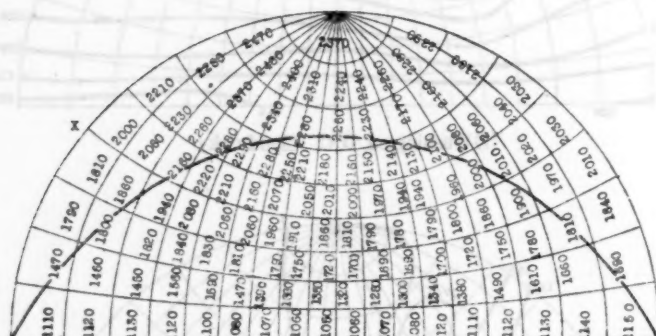
FIG. 2.—Sky brightness in millilamberts. Sun's position indicated by X. Stereographic projection.



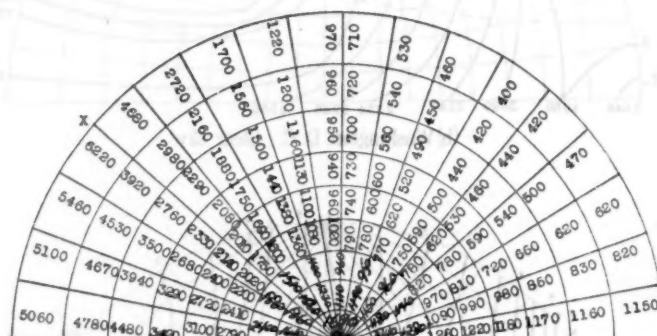
(a) Sky covered with thin clouds.



(d) Cloudy sky.



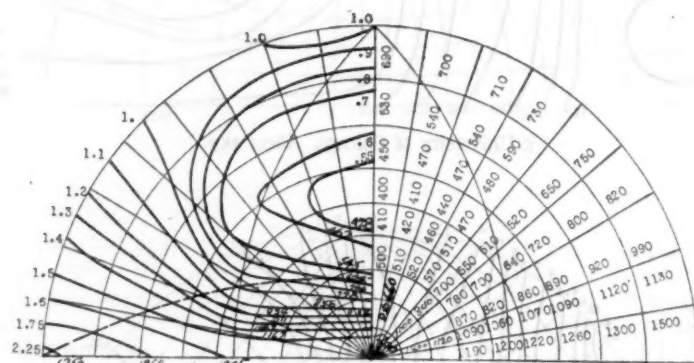
(b) Cloudy sky.



(e) Clear sky.



(c) Cloudy sky.



(f) Clear sky.

FIG. 3.—Sky brightness at Washington, D. C., in millilamberts. Solar altitude 40°, and position indicated by X in (a), (b), (c), and (e). Stereographic projection.

white clouds reflect about 78 per cent of the light that they receive, and that the cloud surfaces may be from five to ten times as bright as adjacent patches of blue sky.

TABLE 1.—Means of daylight illumination measurements.  
CLOUDLESS SKY.

Place.	Solar altitude.	Solar illumination.		Skylight illumination.					
		Normal incidence.	On horizontal surface.	On horizontal surface.	On vertical surface.				
					Azimuth from sun.				
					0°	45°	90°	135°	180°
		F. C.	F. C.	F. C.	F.	F. C.	F. C.	F. C.	F. C.
Chicago, U.	6	1,220	205	339					
Washington	24	4,870	2,020	996					
Chicago, U.	22	5,840	1,850	912					
Chicago, F.	23	3,880	1,260	939					
Washington	42	7,920	5,560	1,340	1,580	1,320	849	1,575	1,534
Chicago, U.	41	6,410	4,060	1,400					
Chicago, F.	41	6,100	3,440	1,300					
Washington	60	8,970	6,450	1,740	1,440	1,280	960	1,760	1,580
Chicago, U.	60	7,840	7,130	2,000					
Chicago, F.	58	8,380	7,590	1,380					

PARTLY CLOUDY SKY.

Chicago, U.	20	2,260	508	1,180					
Chicago, F.	20		1,080	1,050					
Washington	40	4,520	3,150	3,040	2,800	2,470	1,560	1,020	1,762
Chicago, U.	40	4,660	2,800	1,530					
Chicago, F.	40	5,320	2,690	2,160					
Washington	60	4,550	3,090	3,980	2,310	2,060	1,600	1,1780	1,1,230
Chicago, U.	60	6,910	5,850	3,210					
Chicago, F.	60	5,690	2,660	3,140					
Washington	70	4,280	3,720	4,360	2,180	1,920	1,650	1,1540	1,1,520

CLOUDY SKY.

Chicago, U.	20			840					
Chicago, F.	20			566					
Washington	40			1,990	925	926	849	792	782
Chicago, U.	41			1,736					
Chicago, F.	40			1,315					
Washington	60			2,150	881	941	977	932	929
Chicago, U.	60			1,871					
Chicago, F.	60			792					
Washington	70			3,450	1,290	1,250	1,210	1,220	1,310

<sup>1</sup> Comparison with Table 5 indicates that these values are too high, on account of the reflection of direct solar illumination from the blackened interior walls of the photometer shelter.

NOTE.—Chicago, U.—University of Chicago; Chicago, F.—Federal Building, Chicago.

#### SUMMARY OF DAYLIGHT-ILLUMINATION MEASUREMENTS.

In Table 1 are given the means of daylight illumination measurements made at Washington and Chicago. The only important differences to be noted are between the solar illumination measurements at Washington and at the Federal Building, Chicago. With the sun not more than 40° above the horizon the latter average less than 80 per cent of the former. The Washington measurements are also a few per cent higher than those obtained at Mount Weather, Va., in 1914.<sup>7</sup>

There is a marked increase in direct solar illumination with increase in solar altitude, especially on a horizontal surface, and also an increase in sky illumination on a horizontal surface. The increase in the illumination on vertical surfaces is not so marked, and the difference between the illumination on a surface facing 0° and 180°, respectively, in azimuth from the sun, grows less with increased solar altitude.

Direct solar-illumination measurements show extreme departures from the mean value of about ±30 per cent with solar altitude 40°, ±20 per cent with solar altitude 60°, and ±12 per cent with solar altitude 70°. Sky

illumination on a horizontal surface, with few or no clouds present shows variations from the mean of about ±40 per cent regardless of solar altitude. In the case of both solar and sky illumination, however, the extreme plus departures are greater than the extreme minus departures.

The illumination on vertical surfaces with the sky partly covered with clouds shows variations of about ±60 per cent on each side of the mean. Or, roughly, the maximum sky illumination measured on a vertical surface has been about four times the minimum illumination measured on the same surface. Illumination from a cloudy sky shows about the same order of variation.

#### COMPUTATION OF DAYLIGHT ILLUMINATION FROM SKY-BRIGHTNESS MEASUREMENTS.

Moore and Abbot<sup>8</sup> have shown that the illumination on a horizontal surface may be computed from sky brightness measurements as follows:

Suppose the hemispherical sky surface of radius  $r$  to be divided into elementary horizontal zones, and let the angular altitude of these zones above the horizon =  $\theta$ . Then the radius of any zone =  $r \cos \theta$ , and the circumference =  $2\pi r \cos \theta$ . Let the width of the zone =  $r d\theta$ ; its area =  $2\pi r^2 \cos \theta d\theta$ . Let the sky brightness everywhere = one unit, and the horizontal light intensity due to the brightness of an elementary zone =  $dI$

$$\text{Then } I = \int_{\theta=0}^{\theta=\frac{\pi}{2}} 2\pi r^2 \cos \theta \sin \theta d\theta \\ = \pi r^2 \sin^2 \theta \quad (1)$$

Taking zones 10° in width as in chart 10, and solving equation (1) for the limiting values assigned to  $\theta$ , we obtain the relative values of  $I$  given in Table 2, after dividing out the common factor  $\pi r^2$ .

TABLE 2.—Relative values of  $I$  for different values of  $\theta$ .

$\theta =$	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°	60°-70°	70°-80°	80°-90°
$I =$	0.030	0.087	0.133	0.163	0.174	0.163	0.133	0.087	0.030

These relative values are to be multiplied by the average brightness of the respective zones, which is best obtained by first estimating the average brightness of spherical polygons measuring 10° on a side, as shown on figure 3, (b), which is based on the equal brightness lines of figure 2 (f). The average brightness of each zone is then easily computed from the brightness of the polygons it contains.

A similar method may be followed in computing the illumination intensity from the sky brightness on any plane surface, as, for example, upon a vertical surface, provided the zones of equal width are drawn concentric about a line normal to that surface. Figure 3, (c) and (d), are examples of such concentric zones, and are arranged for the computation of the illumination upon vertical surfaces facing 90° and 180° in azimuth, respectively, from the sun. These two figures are also constructed from the data given on figure 2 (f).

As an illustration of the computation we have taken the data given in Table 3, which is derived from readings on three cloudy days in May, 1921, with the sun 40° above the horizon. Table 4 gives the different steps of the computation, and the resulting illumination in foot-candles.

<sup>8</sup> Moore, A. F., and Abbot, H. L. The Brightness of the Sky. *Smithsonian Misc. Collection*, vol. 71, No. 4, p. 14.

<sup>7</sup> MONTHLY WEATHER REVIEW, December, 1914, 42: 652.

TABLE 3.—Sky brightness in terms of zenith brightness; cloudy sky.

(Mean of May 25, 26, and 27. Solar altitude=40°.)

Azimuth from sun.	Altitude of point observed.							Zenith brightness.	Measured illumination, vertical surface.
	2°.	15°.	30°.	45°.	60°.	75°.	90°.		
0°	0.476	0.715	1.069	1.174	1.166	1.173	1.00	Ml. 2,098	F. C. 978
45°	0.439	0.624	0.835	0.977	0.980	0.966	1.00	2,290	1,026
90°	0.320	0.433	0.611	0.722	0.936	0.929	1.00	2,564	799
135°	0.342	0.477	0.663	0.708	0.941	1.102	1.00	2,764	725
180°	0.325	0.475	0.670	0.641	0.806	0.826	1.00	2,932	693
Mean								2,530	
Horizontal surface illumination									1,718

TABLE 4.—Illumination computed from sky brightness.

On vertical surface 90° from sun.					On horizontal surface.		
(1) Sky zone (degrees from normal).	(2) (From Table 2.) Relative value.	(3) (From chart.) Sky brightness.	(4)= (2)×(3). Vertical component (3).	(5)= (4)×0.929. Illumination.	Sky brightness.		(8)= (7)×0.929. Illumination.
					(6) (From chart.)	(7)= (2)×(6).	
		Ml.	Ml.	F. C.	Ml.	Ml.	F. C.
0-10°	0.030	980	29.40		1,048	31.44	
10-20°	0.087	1,075	93.52		1,352	117.62	
20-30°	0.133	1,232	163.86		1,693	225.17	
30-40°	0.163	1,439	234.56		1,957	318.99	
40-50°	0.174	1,581	275.09		2,057	357.92	
50-60°	0.163	1,787	291.28		2,269	369.85	
60-70°	0.133	1,908	253.76		2,404	319.73	
70-80°	0.087	2,018	175.44		2,498	217.48	
80-90°	0.030	2,091	62.73		2,530	75.90	
Total			1,579.64			2,034.10	1,890
1/2 total			789.8	734			

On vertical surface 180° from sun.					Shading by buildings on opposite side of street. h=w.		
					Sky obscured.		(8)= (7)×0.929.
					(6) (From Fig. 3(d).)	(7)= (4)×(6).	
		Ml.	Ml.	F. C.	Per cent.	Ml.	F. C.
0-10°	0.030	949	28.47		100.0	28.47	
10-20°	0.087	1,068	92.92		100.0	92.92	
20-30°	0.133	1,230	163.59		100.0	163.59	
30-40°	0.163	1,357	221.19		100.0	221.19	
40-50°	0.174	1,460	254.04		81.9	208.00	
50-60°	0.163	1,537	250.53		38.6	96.90	
60-70°	0.133	1,672	222.38		19.5	43.30	
70-80°	0.087	1,832	159.38		9.5	15.10	
80-90°	0.030	1,828	54.84		3.2	1.75	
Total			1,447.34			871.22	
1/2 total			723.7	672		435.61	403

It will be noted that the measured illumination on vertical surfaces is a little greater than the computed, perhaps because of the reflection of some light from the blackened walls of the shelter. On the other hand, the computed illumination on a horizontal surface is 10 per cent greater than the measured, but this discrepancy is not great when we consider the variation in sky brightness indicated by the zenith brightness measurements.

The results of a computation of the illumination upon vertical surfaces facing 180° in azimuth from the sun, from the sky brightness measurements made at the American University, District of Columbia, and the Federal Building, Chicago, are given in Table 5. The excess in the measured illumination on a vertical surface facing 180° from the sun, with the sky clear, as given in Table 1, over the computed values for Washington given in Table 5, is fully explained by the reflection of direct

sunlight from the blackened interior walls of the photometer shelter. With a cloudy sky it will be noted that the difference is small.

TABLE 5.—Illumination on a vertical surface facing opposite the sun computed from sky brightness.

Place.	Character of sky.	Solar altitude.	Illumination.		
			F. C.	Ratio	
				Chicago	Washington
				Observed.	Corrected for difference in zenith brightness.
Washington.....	Clear.....	20	298		
Chicago.....	do.....	20	207	0.694	
Washington.....	do.....	40	363		
Chicago.....	do.....	40	253	.697	
Washington.....	do.....	60	498		
Chicago.....	do.....	60	390	.782	
Washington.....	Cloudy.....	40	737		
Chicago.....	do.....	40	410	.556	0.599
Washington.....	do.....	60	957		
Chicago.....	do.....	60	349	.365	.576

Since August 1 was the only cloudy day on which sky brightness measurements were made at the Federal Building, Chicago, the zenith brightness of this day can not be considered the average for cloudy skies at Chicago. The ratio of the mean zenith brightness with a cloudy sky at Washington to the zenith brightness measured at Chicago on August 1 is 1.059 for solar altitude 40° and 1.578 for solar altitude 60°. Multiplying the observed ratios for a cloudy sky in Table 5 by the ratios just given, respectively, we obtain 0.599 and 0.576, which probably better represent the relative illumination intensities at the two places than the observed ratios.

The data of Table 5 lead to the following conclusion: The daylight illumination on a vertical surface facing opposite the sun, and with an unobstructed exposure to the sky, in the Loop district of Chicago under summer conditions as regards smoke, averages only about two-thirds as intense as the illumination on a similarly exposed surface at Washington under similar sky conditions with respect to clouds, except when the sun is more than 40° above the horizon and the sky is clear.

#### THE SHADING EFFECT OF BUILDINGS AND OTHER OBJECTS.

For computing the shading effect of buildings on the opposite side of a street we have the following equation:

Let  $w$  = the width of the clear street space,  $h$  = the height to which opposite buildings extend above the center of a window that is under consideration,  $\alpha$  = the angle between a line normal to the window surface and a horizontal line drawn to a point  $p$  on the row of buildings, and  $\theta$  the angular height of the building above the point  $p$ , as seen from the center of the window. Then

$$\tan \theta = h/w \sqrt{\frac{1}{1 + \tan^2 \alpha}} \quad (2)$$

Let  $h = 2w$ ,  $w$ , and  $1/2w$ , respectively, and let the row of buildings be of infinite length. We obtain the following relations between  $\alpha$  and  $\theta$ .

	$\alpha =$	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
$h/w = 2$	$\theta =$	63.4°	63.1°	62.0°	60.0°	56.9°	52.1°	45.0°	34.4°	19.1°	0.0°
$h/w = 1$	$\theta =$	45.0°	44.6°	43.3°	40.9°	37.5°	32.7°	26.6°	18.9°	9.8°	0.0°
$h/w = 1/2$	$\theta =$	26.6°	26.2°	25.2°	23.4°	21.0°	17.8°	14.0°	9.7°	5.0°	0.0°

On figure 3, (b) and (c), the area below the broken line represents the sky area cut off by a row of buildings where  $h=2w$ ; on figure 3, (d), it represents the sky area cut off by buildings where  $h=w$ , and on figure 3, (f), it represents the area cut off by buildings where  $h=\frac{1}{2}w$ .

It is to be noted that any obstruction on the horizon cuts off the portion of the sky that is most efficient for lighting vertical surfaces, such as the side windows of buildings, and especially if the sky is clear.

In Table 4 is given an example of the computation of the shading of a window by a row of buildings opposite,

following brief extracts have been made with the consent of Mr. Smirnoff and Mr. R. B. Patterson, engineer for the company:

The District of Columbia has a double system of electrical supply; alternating current for the greater part of the residential section and direct current for the greater part of the business section. There is a comparatively small industrial load in the District, a condition favorable to a study of the relation between daylight and load.

It has been found that during the day in the business section a sudden increase in current consumption occurs when the daylight illumination intensity falls below 1,500-foot candles. The lower the intensity the higher the current consumption, but fluctuations in intensity above 1,800-foot candles have only a negligible effect.

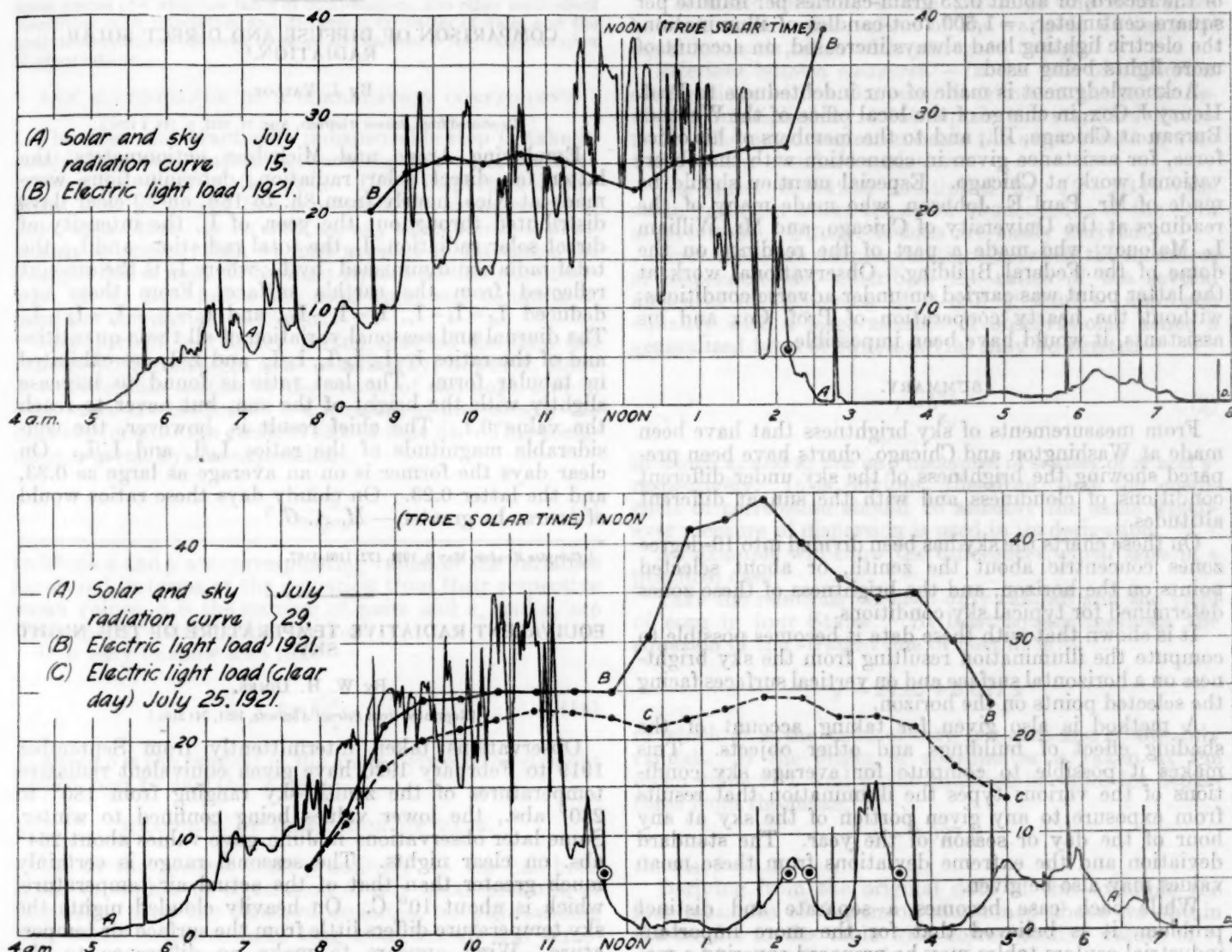


FIG. 4.—Comparison of solar and sky radiation intensity with electric light load.

with  $h=w$ , using the data contained in Fig. 3 (d). In this case the proportion of skylight cut off equals 405/672, or about 60 per cent.

It is possible to extend these computations so as to determine the illumination resulting from exposure to any known area of the sky, which would, of course, vary with the character of the sky and time of day.

The reflection of light from ground surfaces and from the walls of buildings and other objects is an important subject that will receive future consideration.

The utility of measurements and computations such as the foregoing is clearly shown by recent unpublished studies by Mr. A. Smirnoff, statistician of the Potomac Electric Power Co., Washington, D. C., from which the

There are two general causes of decrease in daylight illumination: (1) Decreased solar altitude, and (2) increased cloudiness.

With reference to (1) the time of the occurrence of an intensity of 1,500 foot-candles with a clear sky at different latitudes has already been computed.<sup>9</sup> While we expect to increase the accuracy of these computed values, Mr. Smirnoff has already pointed out their present utility.

With reference to (2) the greatest interest attaches to the rapid diminution in daylight intensity in summer in connection with severe thunderstorms. On July 15 of

<sup>9</sup> Kimball, Herbert H. Variations in the total and luminous solar radiation with geographical position in the United States. *MO. WEATHER REV.*, November, 1919, 47; pp. 789-790, figs. 16-18.

this year in Washington shortly after 3 p. m. an unusually severe thunderstorm caused the daylight intensity to fall rapidly to something like a foot-candle, and the resulting sudden increase in load was probably one of the factors that put the Electric Power plant temporarily out of commission. The darkness lasted for about an hour. Figure 4, which was prepared by Mr. Smirnoff, enables us to compare the intensity of solar and sky radiation on this day, and also on July 29, 1921, with the electric lighting load. It will be noted that whenever the radiation intensity fell to about six units on the vertical scale of the record, or about 0.25 gram-calories per minute per square centimeter, = 1,500 foot-candles of illumination, the electric lighting load always increased, on account of more lights being used.

Acknowledgment is made of our indebtedness to Prof. Henry J. Cox, in charge of the local office of the Weather Bureau at Chicago, Ill., and to the members of his office force, for assistance given in connection with the observational work at Chicago. Especial mention should be made of Mr. Paul E. Johnson, who made many of the readings at the University of Chicago, and Mr. William L. Maloney, who made a part of the readings on the dome of the Federal Building. Observational work at the latter point was carried on under adverse conditions; without the hearty cooperation of Prof. Cox and his assistants, it would have been impossible.

#### SUMMARY.

From measurements of sky brightness that have been made at Washington and Chicago, charts have been prepared showing the brightness of the sky under different conditions of cloudiness and with the sun at different altitudes.

On these charts the sky has been divided into 10-degree zones concentric about the zenith, or about selected points on the horizon, and the brightness of these zones determined for typical sky conditions.

It is shown that with these data it becomes possible to compute the illumination resulting from the sky brightness on a horizontal surface and on vertical surfaces facing the selected points on the horizon.

A method is also given for taking account of the shading effect of buildings and other objects. This makes it possible to compute for average sky conditions of the various types the illumination that results from exposure to any given portion of the sky at any hour of the day or season of the year. The standard deviation and the extreme deviations from these mean values may also be given.

While each case becomes a separate and distinct problem, it is believed that for the more important industrial centers tables may be prepared covering a majority of cases that will arise, and perhaps differentiating between good and bad illumination.

#### UNIVERSITY COOPERATION IN SKY BRIGHTNESS MEASUREMENTS.

In the discussion of the report of the Committee on Sky Brightness of the Illuminating Engineering Society at the recent convention in Rochester, N. Y., it was suggested that the universities might cooperate in this work by assigning it as the subject of a thesis for an advanced student.

The Weather Bureau would welcome such cooperation, and suggests that universities wishing to undertake this work correspond with Dr. H. H. Kimball, Weather Bureau, Washington, D. C., Chairman of the Committee on Sky Brightness, I. E. S.

It seems desirable that work along this line if undertaken by different individuals or institutions should be coordinated, so that measurements made in different localities may be comparable, and also to avoid unnecessary duplication.—H. H. K.

#### COMPARISON OF DIFFUSE AND DIRECT SOLAR RADIATION.<sup>1</sup>

By J. VALLOT.

[Reprinted from *Science Abstracts*, Aug. 31, 1921, p. 548, § 1384.]

Employing Arago and Michelson actinometers, the latter for direct solar radiation, determinations were made at Nice, hourly from 8h. to 16h. on 30 clear days distributed throughout the year, of  $I_d$ , the intensity of direct solar radiation,  $I_t$ , the total radiation, and  $I_r$ , the total radiation diminished by  $I_r$ ; where  $I_r$  is the amount reflected from the earth's surface. From these are deduced  $I_d = I_t - I_r$ ,  $I_r = I_t - I_d$ , and  $I_c = I_d - I_r$ . The diurnal and seasonal variation of all these quantities and of the ratios  $I_d/I_t$ ,  $I_r/I_t$ ,  $I_c/I_t$ , and  $I_r/I_d$  are exhibited in tabular form. The last ratio is found to increase slightly with the height of the sun, but never to reach the value 0.1. The chief result is, however, the considerable magnitude of the ratios  $I_d/I_t$  and  $I_c/I_t$ . On clear days the former is on an average as large as 0.33, and the latter 0.23. On cloudy days these ratios would of course be greater.—M. A. G.

<sup>1</sup> *Comptes Rendus*, May 9, 1921, 172: 1164-1167.

#### EQUIVALENT RADIATIVE TEMPERATURE OF THE NIGHT SKY.<sup>1</sup>

By W. H. DINES.

[Reprinted from *Science Abstracts*, 1921, 24: 216a.]

Observations taken intermittently from September 1919 to February 1920 have given equivalent radiative temperatures of the zenith sky ranging from 180° to 280° abs., the lower values being confined to winter. Some later observations in June gave values about 264° abs. on clear nights. The seasonal range is certainly much greater than that of the actual air temperature, which is about 10° C. On heavily clouded nights the sky temperature differs little from the surface air temperature. Wind appears to make no difference to the radiation. It is estimated that on clear nights the average rate of net radiation from the earth (for the whole hemisphere) is about 150 gm. cal. per day, though the rate may reach 250 gm. cal. per day.

As regards radiation at various zenith distances, the approximate relative values of the net radiation, 100 denoting the net radiation to the zenith, found for clear nights in the last fortnight of May, were:

Altitude.....	90°	75°	60°	45°	30°	15°	0°
Radiation.....	100	99	96	89	73	43	0

—M. A. G.

<sup>1</sup> *Jour. Roy. Met'l Soc.*, London, Oct., 1920, 46: 406.

## NOTE ON METHODS FOR INDICATING AND MEASURING CORRELATION, WITH EXAMPLES.

By H. W. CLOUGH.

[Weather Bureau, Washington, D. C., May, 1921.]

## SYNOPSIS.

The conventional measure of correlation between two variables  $x'$  and  $y'$  is expressed by the ratio of the mean product of  $x, y$  to the product of the standard deviations of  $x'$  and  $y'$ , viz:  $r = \frac{\sum(xy)}{n\sigma_x\sigma_y}$ , in which  $x$  and  $y$  must be measured from the respective mean values of the variables. The present note indicates methods for securing approximate values of  $r$  with less labor of computation, also other methods of measuring both correlation and dispersion or scatter of data, and the analytical relations between them on the basis of a very large number of observations.

## THE SIGNIFICANCE OF A CORRELATION COEFFICIENT.

The first and practically indispensable step to take in establishing the relation between the two variables is to make a dot chart of the data. If by inspection it appears that a straight line represents the arrangement of dots better than, or as well as, any other line it is practicable to employ, then we may proceed to determine the straight line of best fit by least square methods or otherwise, or we may follow the usual rules and compute at once the correlation coefficient.

Now perfect correlation means that all the dots fall exactly on the straight line. Ordinarily, however, there is considerable scatter or dispersion of the dots, and in such cases the coefficient is a measure of how closely the dots conform to the straight line of best fit. This coefficient is given by the expression

$$r = \frac{\sum xy}{n\sigma_x\sigma_y} \quad (1)$$

in which  $x$  and  $y$  are corresponding values of the variables measured in terms of the deviation from their respective mean values,  $n$  is the number of pairs and  $\sigma_x$  and  $\sigma_y$  are the respective standard deviations.

It is easy to show also that<sup>1</sup>

$$r = b \frac{\sigma_x}{\sigma_y} \quad (1a)$$

in which  $b$  is the tangent of the angle between the straight line of best fit and the  $X$  axis.

## MEASURES OF DISPERSION OF DATA.

Up to the present time practically no use has been made in studies of correlation of any other measure of dispersion than the *standard deviation*, notwithstanding that other measures have long been known and sometimes used in other connections. In what follows it will be shown that any measure of dispersion may be substituted in the second member of equation (1a) for the standard deviation and with identical results, subject only to the limitations of paucity of data or of sampling.

There are several different indexes of the dispersion or scatter of data which vary in relative magnitude but nevertheless bear definite mathematical relations to each other when the number of observations is great and the distribution Gaussian.

The *standard deviation*, much employed in statistical investigations, is the square root of the mean of the squares of the departures from the true mean.

The *mean deviation* is the mean of the departures from the true mean, taken without regard to sign.<sup>2</sup>

The *standard variation*.—By analogy to the standard deviation, this term may be employed to designate the mean of the squares of the variations between consecutive values.

The *mean variation* is the mean of the differences between consecutive values of the variable at assumed equal intervals taken without regard to sign.

*Relations between measures.*<sup>3</sup>—In the case of numerous observations with a Gaussian distribution the mean deviation multiplied by 1.253 equals the standard deviation. The mean variation bears the same relation, 1 to 1.253, to the standard variation.

The mean deviation multiplied by  $\sqrt{2} = 1.414$  = the mean variation where the order of succession of the data is fortuitous. Other relations are easily derived.

Since there are definite relations between the measures of dispersion just described, the ratios of the several measures of dispersion of  $x'$  and  $y'$  tend to approach equality with a large number of observations, hence a generalized form of equation (1a) may be written

$$r = b \frac{s_x}{s_y} \quad (2)$$

in which  $s_x$  and  $s_y$  are any measures of scatter of  $x'$  and  $y'$  respectively. It is obvious, therefore, that the coefficient of correlation should be sensibly the same whichever measure of dispersion is used in its derivation.

An example will show the differences which arise in a practical case.

Take the relations between July rainfall and the yield of corn in four States.<sup>4</sup> By least square methods the equation of the straight line of best fit is

$$y' = 24.07 + 2.027 x'$$

in which  $y'$  is the yield of corn per acre and  $x'$  the July rainfall. If the origin of coordinates is taken at the mean value of  $x'$  and  $y'$  the equation becomes for departures from the mean,

$$y = 2.027 x$$

that is,  $b = 2.027$ .

Deriving from the original data of this example the four measures of dispersion mentioned above we obtain the results in the table with corresponding values of  $r$ , derived by substituting in equation (2),

## Measures of dispersion and correlation.

	Rainfall.	Acre yield of corn.	Correlation coefficient.
	$s$ .	$s$ .	$r$ .
Standard deviation.....	1.31	4.45	0.60
Mean deviation.....	1.07	3.46	.63
Standard variation.....	2.08	6.80	.60
Mean variation.....	1.63	6.52	.51

<sup>1</sup> For an abridged method of computing this, see Marvin, Theory and Use of the Periodocrite. MO. WEATHER REV., Mar., 1921, 49: 120.

<sup>2</sup> For discussion of the various measures of dispersion and reference to original sources see Clough, A Statistical Comparison of Meteorological Data with Data of Random Occurrence. MO. WEATHER REV., Mar., 1921, 49: 125.

<sup>3</sup> Marvin, C. F.: Elementary Notes on Least Squares. Loc. cit. p. 564.

<sup>4</sup> Marvin, Chas. F.: Elementary Notes on Least Squares, etc. MO. WEATHER REV. 44: 567.

The divergence between the values of  $r$  in the table is largely explained by the relatively small number of observations, 28. The coefficient of correlation computed by the method of variations is somewhat inferior, in dependability, to that by the usual method unless the data are sufficiently numerous.

#### SHORT METHOD.

It is easy to see that equation (2) furnishes a short method of computing a correlation coefficient with considerable accuracy, as follows:

By simple inspection, locate on the dot chart the straight line of approximately the best fit. For this purpose locate on the chart a master dot representing the mean values of the variables. The line of best fit must pass through this dot and be so inclined as to best represent all the dots. The equation of this line referred to the master dot as origin is  $y' = bx'$  or  $y' = a + bx'$  if referred to any parallel axes with origin not on the line. The value of  $b$  may be easily found by taking the ratio  $y' \div x'$  for any point on the line more or less distant from the master dot.

This value of  $b$  together with the ratio of, say, the mean deviation of the variables, a quantity much more easily computed than the ratio of the standard deviations, gives at once by equation (2) a value of  $r$  which is increasingly accurate as  $r$  is greater.

In addition to its use in this short method of computing a coefficient of correlation, the mean deviation as a measure of dispersion will frequently suffice for other purposes and make unnecessary the tedious computations of standard deviations ordinarily resorted to.

*Correlation by algebraic signs.*—The writer has found the following still shorter method of deriving an index of correlation very useful when a large number of groups of observations must be examined and the employment of the usual methods would be impracticable. The method also serves as a preliminary test for determining quickly if sufficient correlation exists, to justify computation by the more exact methods:

Count the number of times when the deviations of  $x'$  and  $y'$  from their respective means, or when the variations between consecutive values have the same sign. Divide by the number of observations. The ratio thus obtained is a rough index of the correlation. If there is a positive correlation, the percentage will range between 0.50 for absence of correlation to 1.00 for perfect correlation. If there is negative correlation it will range between 0.50 for absence of correlation to 0 for perfect correlation. To reduce this ratio to a type of correlation coefficient, subtract 0.50 from it and multiply by 2. In general the coefficient by this method is somewhat less than that computed by the usual method.

#### REMARKS ON THE PREPARATION OF DATA.

Correlation between two variables implies similarity of fluctuation due to a causal relation which one bears to the other or which both bear to a third variable. Fluctuations in a variable are usually measured by deviations from a mean. Meteorological variables are either daily observations or weekly, monthly, or yearly means. All meteorological data are characterized by fluctuations of varying length and amplitude. The fluctuations may be classed, in general, as short period or long period fluctuations, which latter may be clearly disclosed only when the minor fluctuations are eliminated. If it is desired to correlate two series of data it is necessary to discriminate carefully between the short period, which may be likened

to accidental fluctuations, and the long period or systematic fluctuations, otherwise the correlation may be spurious. There may be high correlation between the larger fluctuations and low correlation if the smaller fluctuations are considered, or vice versa. For example, take the daily temperature normals for the month of March for two 20-year periods. If the two series of normals be plotted as two variables,  $x'$  being the normal value for any day of March of the first period and  $y'$  the normal value for the corresponding day of March of the second period, the chart will show a pronounced tendency for high values of one period to be associated with high values of the second period. This is a correlation, however, due to the annual change common to both periods. If this seasonal variation be eliminated by plotting deviations from the true normal, derived from the whole 40-year series by harmonic analysis, the resulting plot shows that there is no correlation between the residuals for corresponding dates of the two 20-year periods.

Another illustration is furnished by daily maxima and minima of temperatures, at any locality. Suppose we have daily maxima and minima for April. If the annual variation common to both variables be not eliminated, a correlation coefficient manifestly too high will be the result. By eliminating the annual variation the coefficients at different places are comparable. Thus the correlation is found to be very high on a mountain peak and low in a valley having a large daily range.

The correlation between the daily values of the vapor pressure at the surface and the total amount of the water vapor in the whole atmosphere vertically above the station as determined at Mount Wilson, Calif., by spectroscopic methods further illustrates this principle. Obviously there is correlation between the two variables. Both variables are high in summer and low in winter. On the other hand if one variable shows an increase from one day to the next, the other may show a decrease and in fact there is small correlation between their day-to-day fluctuations. Taking a large number of observations, the vapor pressure at the surface multiplied by a constant gives approximately the total vapor content of the whole atmosphere, but there are wide variations in this ratio from day to day. We may desire a correlation which gives an indication of the reliability of the spectroscopic method, assuming that taking the averages of the spectroscopic determination and the surface values over a long period of time, there should be substantial agreement between their variations. By combining the data into 5 to 10 day means the minor fluctuations which show little similarity are smoothed out, and there is then disclosed a high correlation between the two variables. At Calama, Chile, a correlation of +0.95 was found from the weekly means. On the other hand if we seek the correlation between the small day to day fluctuations, the seasonal variation must be first eliminated. Then the irregular short-period fluctuations common to both variables may be eliminated by taking deviations from consecutive seven-day means. These residuals are the data to be employed in computing the correlation coefficient.

The relation between two variables may be such that the value of one depends largely upon the value of the other but one variable is subject to an influence not affecting the other. The minor fluctuations synchronize but the major fluctuations are unlike. This is illustrated by the relation between the atmospheric transmission coefficient and the solar intensity at air-mass

zero. Both quantities are evaluated in a single operation which consists in fitting a straight line to plotted pyrliometric observations of the solar intensity at varying air masses, and prolonging it to the zero of abscissas or air mass zero. The data show pronounced correlation in respect to the minor day-to-day fluctuations, as shown by the method of correlation by variations, while by the usual method of correlation by deviations from the mean, little correlation results, owing to the existence of long-period changes in the transmission coefficient without corresponding changes in the solar intensity.

*Variation in the mean.*—The mean may vary either systematically through long-period fluctuations or accidentally, as by a change of hours of observation, or exposure of instruments, rendering the data nonhomogeneous. A gradual or abrupt change in the regimen of

a river or an increase in the number of crop reporting points in a State over a term of years or an increase in yields due to cultivation are further examples of such actual or accidental changes in the mean. Frequently it is difficult or impossible to distinguish between an actual change in the mean and a true secular change, both of which may cause deviations which are not present in the variations of another variable with which a relation is sought. The usual method of correlation by deviations yields results more or less spurious. In all such cases the method of correlation by variations should be employed, since it is quite independent of nonsimultaneous changes in the means of the two variables, either accidental or systematic. The usual method by deviations is, however, appropriate in the case of systematic changes if the secular change be first eliminated by taking deviations from means varying with the general trend.

## THE TEXAS FLOODS OF SEPTEMBER, 1921.

### GENERAL DISCUSSION.

By B. BUNNEMEYER, Meteorologist.

[Weather Bureau, Houston, Tex., Oct. 10, 1921.]

Torrential rains in southern and central Texas from September 8 to 10, inclusive, 1921, resulted in phenomenally rapid floods in streams and lowlands, especially in Bexar, Travis, Williamson, Bell, and Milam Counties, and caused the death, so far as is known, of 215 persons and property loss estimated at over \$19,000,000. This exceeds the havoc wrought by the record-breaking floods of December, 1913, when 177 persons lost their lives and property valued at nearly \$9,000,000 was destroyed. But in December, 1913, there were practically no crops in the fields.

The heaviest precipitation was reported from Taylor, Williamson County, where 23.11 inches occurred in 24 consecutive hours, September 9-10, which is the greatest 24-hour rainfall of record for the State of Texas, the previous record being 20.60 inches at Montell, Uvalde County, on June 28-29, 1913.

Throughout the stricken area traffic by railroad, street car, or other conveyances was interrupted by washouts, loss of bridges, and accumulation of debris; telegraph, telephone, electric light, and other public services were crippled, and numerous small houses and other structures were carried off by the currents that swept through cities and rural districts, resulting in the loss of many lives. Much other damage was done, largely to crops, mostly corn and cotton. Considerable damage was also caused by violent thunderstorms and squalls occurring in various localities during the downpour, although it was overshadowed by the havoc due to the flood.

While creeks and other tributaries rose to appalling heights, the trunk streams were much less seriously affected than was anticipated from the deluge, the redeeming features being a previously dry soil and low streamflow. The run-off was swift and much of the back water did not return to the streams, resulting in a rapid diminution of the volume of water rushing toward the Gulf of Mexico. The subsidence of the flood wave on the Brazos River was so rapid that flood stage was not attained in the lower reaches of that stream at or below Rosenberg, while at Valley Junction, where the water poured in from the Little River, the stream was 14.2 feet above flood stage and only 0.8 foot below the record high watermark of the December, 1913, flood.

*Cause of the rains.*—Evidence is strong that the precipitation was the result of the breaking-up in Texas of the disturbance that moved westward toward the Mexican coast south of Tampico on September 7, 1921. Although the distribution of the pressure was such that the storm could not be charted, the shifting winds, the progressive northeastward extension of the rainfall area, and the profound agitation of the atmosphere as evidenced by violent squalls and thunderstorms over the stricken sections, can hardly be ascribed to any other cause. The storm apparently moved in from Mexico over Webb County and passed in a northeasterly direction over Bexar, Comal, Hays, and Travis Counties into Williamson, Bell, and Milam Counties where it abruptly dissipated. Milam County borders on the west bank of the Brazos River, and there was very little precipitation along the east bank of that stream. An area of high pressure of apparently feeble energy backing in over eastern Texas was probably a contributory cause of the record breaking rains and their abrupt termination near the Brazos River. While the rains were disastrous to life and property over a large area, there were many localities in southern Texas where they proved beneficial by relieving the drought, reviving ranges, and providing stock water.

*Warnings.*—The flood waters accumulated so rapidly in creeks and lowlands that residents were taken completely by surprise. Warnings of impending rises were issued, however, immediately upon the receipt of rainfall reports to the main streams on which river stations are maintained. On the morning of September 9, to the lower Rio Grande from Rio Grande City to Brownsville; and on September 10 to the Colorado below Austin, and to the Brazos from Valley Junction to Richmond, with injunctions to keep live stock from the lowlands and protect other interests. Warnings were repeated on September 11 to residents along the Colorado and Brazos, and extended along the latter stream from Richmond to Freeport. Thereafter residents were kept informed daily of the progress of the floods until danger was over. Similar warnings and injunctions were issued September 11 to the lower Guadalupe. Earlier warnings were not advisable as there were no data available to justify them.

Reports received up to that time from the upper Guadalupe drainage basin indicated rainfall too small to affect the streamflow, considering the August drought. Long distance calls were numerous and planters heeded the warnings even after it became apparent that there would be no danger in the coast sections for, as some of

with river 8.6 feet and rising, and points below were warned accordingly. The flood wave moved downstream at a rapid rate, Rio Grande City having a rise of 17.8 feet in 24 hours to a stage of 18 feet, or 3 feet above flood stage, by the morning of September 10, which was the maximum stage reported. On the morning of

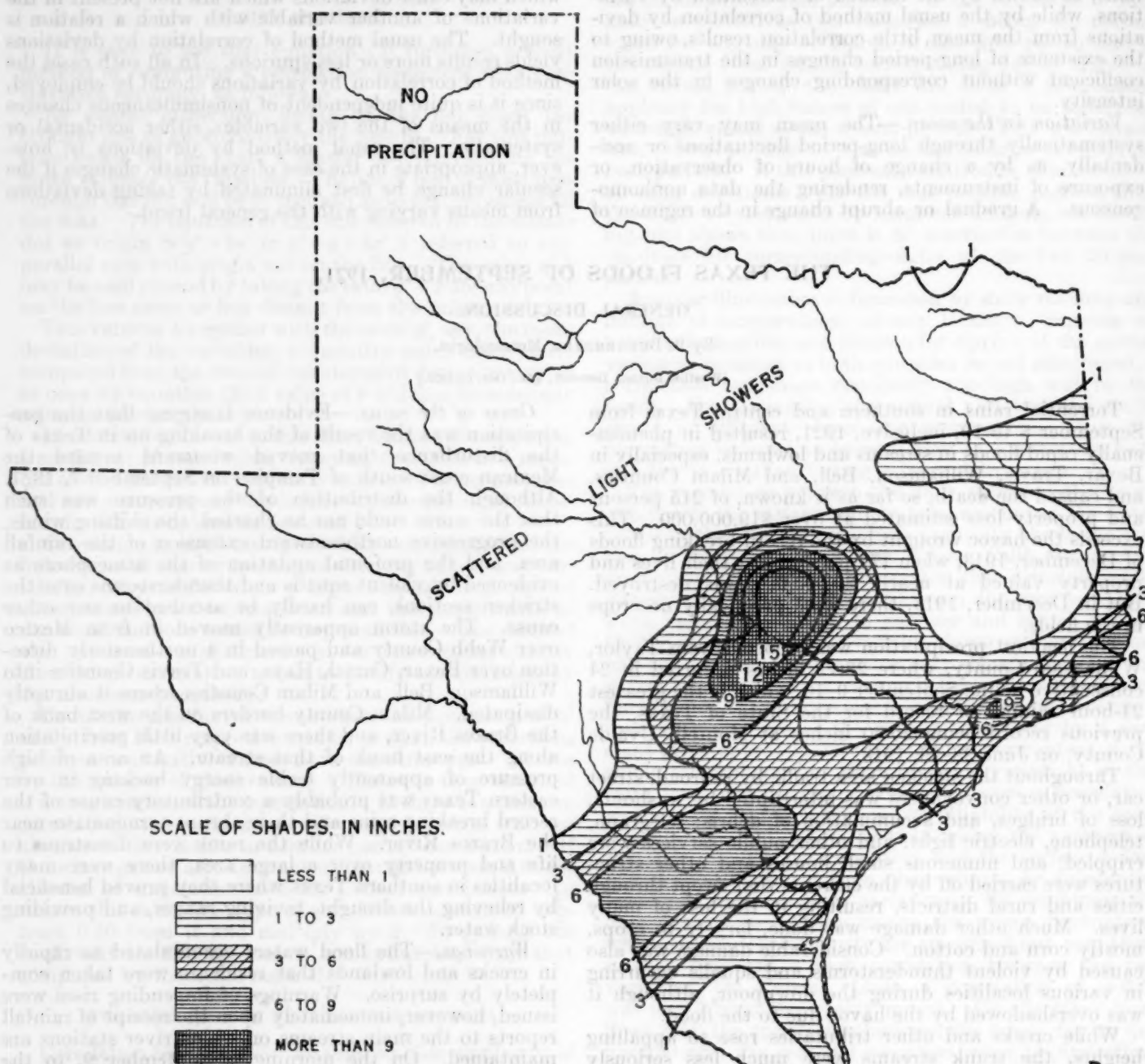


FIG. 1.—Texas rainfall, Sept. 7-11, 1921.

them stated, "the corn has to be hauled in and we might as well do it now as later."

River service is not maintained on the Nueces, San Antonio, or Little Rivers, but reports of all heavy rains over the Little River drainage were repeated to Cameron as soon as received at this office.

**Flood of the Rio Grande.**—On September 9, Laredo reported a rainfall of 6 inches for the preceding 24 hours

September 11 the stream was within banks. The crest of the rise passed Mission on September 11 with a maximum stage of 17.5 feet, which is well below flood stage. There was no damage from the rise.

**Flood of the Guadalupe.**—Unusually heavy rains over the San Marcos and upper Guadalupe drainage basins resulted in a rapid rise of the stream at Gonzales. Blanco reported a total precipitation of 7.85 inches, San Marcos

of 11.50, and New Braunfels of 9.56 inches, while several other stations reported amounts ranging from 2 to 3 inches. The initial rise at Gonzales amounted to 21.9 feet from 1.3 feet at 7 a. m. September 10 to 23.2 feet at 7 a. m. September 11. (Flood stage, 22 feet.) The crest of the flood occurred at 7 p. m. of that date, with a stage of 31.4 feet and stream approximately one-fourth mile wide. The stream fell rapidly during September 13, and by 7 a. m. next morning was down to 7.1 feet. The damage from the high water consisted principally of the loss of low valley corn. There was no loss of live stock. County authorities estimate the damage for the entire county of Gonzales at \$3,500.

The flood wave reached Victoria September 13 with an initial rise of 13 feet in 24 hours and to a stage of 14.7 feet. Thereafter the rise was much slower and continued until September 16, when the gage showed 20.5 feet, or 4.5 feet above flood stage, which was the maximum stage reported. The subsidence of the high water was rapid and by the morning of September 17 the stream was down to 8.1 feet. There was only a slight overflow at Victoria from water backing into low places and no damage.

While the flood loss on the Guadalupe from Gonzales to its mouth was insignificant, considerable damage occurred from the rains in Blanco, Hays, Comal, and Guadalupe counties, the total being estimated at \$218,500.

*Flood of the Colorado.*—Terrific rains on September 9 and 10 in Burnet and Travis counties caused a rapid flooding of the Colorado River below Austin. Fairland in Burnet County reported 8.70 inches for the two days, Marble Falls in the same county, 16.50 inches, and Austin in Travis County, 19.03 inches. During the 24 hours ending 7 a. m. September 10 the rainfall at Austin was 18.25 inches. Notwithstanding the heavy rains in Burnett County, the maximum stage reported from Marble Falls was only 3.2 feet. At Austin, however, the stream rose rapidly from 0.8 foot at 7 a. m. September 9 to 19.0 feet, or 1 foot above flood stage, by midnight of September 10, which was the maximum stage attained. The overflow of the Colorado caused no damage at Austin, all losses being caused by the floods of creeks and lowlands before the waters reached the main stream. The damage to highways and bridges was \$600,000, to crops in the fields \$225,000, and to live stock \$25,000. Violent thunderstorms and squalls caused an additional damage of \$30,000 at Creedmor and Austin.

The flood wave moved rapidly downstream, and at Smithville, Bastrop County, the stream rose from 1.4 feet on the evening of September 9 to 22.1 feet by 7 p. m. September 10 (flood stage 24 feet). The crest of the flood passed at noon, September 11, with stage 26.0 feet. The subsequent fall was equally rapid, and by 9 a. m. September 12 the water was within banks, and 10 hours later down to 12 feet. Smithville is located on a bluff forming the right or south bank of the river, but the left bank is low and the lowlands on that side were submerged for a distance varying from one-half to two miles at the peak of the flood. The damage to crops is estimated at \$6,000, including loss of farm animals, and damage to roads and bridges at \$2,000. That the crop loss was not greater is due to the fact that the first picking of the cotton crop had been made and that about 65 per cent of the corn had been gathered.

At La Grange, Fayette County, which is traversed by the Colorado after it leaves Bastrop County, the damage to crops is estimated at \$15,000, loss of live stock at \$1,500, and damage to other property at \$750; but

reports property valued at \$20,000 saved by warnings. Much corn in the lowlands could have been saved if the fields had not been so wet. As it was it took four horses or mules to a wagon to haul in corn.

At Columbus, the lowest river station on the Colorado, the stream rose from 5.4 feet September 10 to 23 feet by next morning and continued to rise until about 7 a. m. September 13, when the maximum height, 33.8 feet, or 5.8 feet above flood stage, was recorded. During the next 24 hours the stream fell 15.3 feet. The damage to crops and property was reported very small, and there was no loss of live stock, nor was any damage reported from places below Columbus. Evidently the flood wave flattened out rapidly.

*Flood of the Brazos.*—This flood was remarkable from the fact that it was caused by tremendous rains over a single tributary, the Little River, which empties into the Brazos just above Valley Junction, and that the large volume of water spread out at an exceedingly rapid rate as it rushed downstream.

The Little River with its tributaries drains an area of probably 7,000 square miles, but in this case only the lower portions of this area, comprising Williamson, Bell, and Milam Counties, were flooded from the terrific downpour. The total rainfall for two days amounted to 23.98 inches at Taylor and to 14.43 inches at Georgetown, both located in Williamson County; while Temple, in Bell County, recorded for the same period 11.55 inches, and Cameron, in Milam County, 13.30 inches. The Little River and tributaries rose to unprecedented heights. At Georgetown the San Gabriel River and Berrys Creek were reported over 7 feet higher than ever known before. The damage was great and two deaths occurred. Some houses and much corn and cotton were washed away, but pastures were benefited.

At Taylor at the height of the flood the water ran from 1 to 3, and in some places 4 feet deep through the streets, washing up pavements and flooding cellars and basements. Bridges and culverts were carried away, and many small houses in the Mexican section south of the business district were washed from their foundations. The greatest damage and loss of life occurred along the San Gabriel River and Brushy Creek, which rose so rapidly that the people were trapped and perished in their own homes. The waters of Brushy and Mustang Creeks, both passing south of Taylor, met and formed a current 10 miles wide. Violent thunderstorms with squalls occurred during the downpour. The property loss in the vicinity of Taylor amounted to \$93,000 and 87 persons, mostly Mexicans, perished in the flood. The total loss in Williamson County is estimated at \$2,205,000 with a death list of 93, including the losses and deaths at Taylor.

Bell County reported a property loss of \$3,700,000, principally of crops, roads, and bridges, and 5 deaths.

Milam County, which receives the run-off from Williamson and Bell Counties, was probably the greatest sufferer from the deluge. The Little River at Cameron stood 4.5 feet higher on September 10, 1921, than it did during the record flood of December, 1913. Measurements were made by Mr. C. W. Lawrence, superintendent of the water works at Cameron. The total damage in Milam County is estimated at about \$6,000,000, and 66 deaths were reported, mostly of Mexicans in the vicinity of Thorndale.

Burleson County, which is just south of Milam County, suffered damage to the extent of \$785,000, but Lee County, which joins both Williamson and Milam Counties, reported practically no loss.

The flood waters from the Little River began to pour into the Brazos just above Valley Junction on Saturday, September 10. The gage at Valley Junction showed a stage of 3.5 feet at 7 a. m. of that date. At 4.30 p. m. the river was up to 25 feet, rising fast, and at 6.30 p. m. bank full. The observer then warned all residents to leave. No gage readings were taken September 11, 12, and 13, but measurements made from marks left by the flood showed that the maximum height was 58.2 feet, only 0.8 foot below the record flood of December, 1913, but 4.2 feet higher than flood of the spring of 1915. The flooded area was approximately 4 miles wide. Cotton and corn were ruined, and railroad tracks and bridges washed out for a distance of 3 miles, suspending travel for six days. There were no deaths. Flood stage at Valley Junction is at 44 feet.

At Washington, near Navasota, the stream began to rise rapidly about 8 p. m. September 10. The initial 24-hour rise amounted to 21.8 feet to a stage of 27 feet at 7 a. m. September 11. During the next 24 hours there was an additional rise of 15.2 feet, and the stream ultimately reached the peak of the flood on the morning of September 14, with gage reading 50 feet. This was 5 feet above flood stage, but 2.9 feet below the flood of April, 1915. At this time the stream varied from 1 to 3 miles in width. The damage is estimated at \$150,000. There was no loss of live stock.

At Hempstead a high-water gage only is maintained on account of the yielding nature of the banks. The maximum stage reported was 40.2 feet, 0.2 foot above flood stage at 7 a. m. September 16. This is 6.3 feet below the flood of April, 1915. The lowest section of the river gage was washed away with the initial rise. The damage from the flood is estimated at \$43,500, including \$1,000 for loss of live stock. The money value of property saved by warnings is estimated at \$100,000. Wallis, Austin County, located below Hempstead, reports \$5,000

damage to cotton and corn, and a saving of 1,500 head of cattle, valued at \$37,500, through the warnings.

Flood stage was not attained at Rosenberg, although the stream was bank full to overflowing near the coast where the land is level and the run-off correspondingly slow. No damage occurred, except that the Freeport harbor entrance had shoaled as a result of the flood and had to be dredged to release a steamer.

Acknowledgment is made of the receipt of reports of damage furnished by county judges of Bastrop, Bell, Blanco, Burleson, Comal, Gonzales, Guadalupe, Hays, Lee, and Wilson Counties.

TABLE 1.—Deaths and losses from September, 1921, floods, so far as reported.

Counties.	Deaths.	Buildings, bridges, roads, etc.	Crops, corn and cotton.	Live stock.	Other damage.	Total losses.
Austin.....	0	0	\$5,000	0	0	\$5,000
Bastrop.....	0	\$2,000	6,000	*	0	8,000
Bell.....	5	500,000	3,000,000	*	\$200,000	3,700,000
Bexar.....	51	5,000,000	*	*	*	5,000,000
Blanco.....	0	0	2,000	0	0	2,000
Burleson.....	0	25,000	750,000	*	10,000	785,000
Comal.....	0	2,000	70,000	*	*	72,000
Fayette.....	0	*	15,000	\$1,500	750	17,250
Gonzales.....	0	1,000	2,500	0	*	3,500
Grimes.....	0	*	150,000	*	*	150,000
Guadalupe.....	0	2,000	20,000	0	*	22,000
Hays.....	0	50,000	20,000	2,500	50,000	122,500
Milam.....	66	*	*	*	*	6,000,000
Travis.....	0	600,000	225,000	25,000	30,000	880,000
Waller.....	0	2,500	37,500	1,000	2,500	43,500
Williamson.....	93	*	*	*	*	2,205,000
Wilson.....	0	15,000	*	*	*	15,000
Total.....	215	6,199,500	4,303,000	30,000	293,250	19,030,750

\* Included in total or other items.

TABLE 2.—Money value of property saved by warnings, so far as reported.

Austin County.....	\$37,500
Fayette County.....	20,000
Waller County.....	100,000
Total.....	157,500

#### THE SAN ANTONIO FLOOD OF SEPTEMBER 10, 1921.

By J. H. JARBOE, Meteorologist.

[Weather Bureau, San Antonio, Tex., Sept. 23, 1921.]

On the morning of September 10, 1921, between the hours of 12:30 and 6:00 a. m. the most destructive flood in the history of this section swept through the city of San Antonio. Buildings, bridges, and streets gave way in the path of the flood and great damage resulted. An area, about 6 or 7 miles long and from one-half to 2 miles wide, including the business section, was inundated to the depth of from 2 to 12 feet. Three separate floods merged into one in the southern part of the city. Fifty-one lives are known to have been lost, and property damage was estimated at between four and five million dollars.

**Rainfall in San Antonio.**—A drought of two months' duration was broken when a shower of 0.53 inch fell between 6 and 7 a. m., September 8. Seventeen hours later, between 12:00 midnight and 1:00 a. m. on the 9th, steady rains began and continued until shortly after 11:00 p. m.—a period of about 23 hours. The crest of the flood came through the city two hours after the precipitation ended.

The amounts of precipitation, as measured at the United States Weather Bureau, are as follows:

	7:00 a. m.	7:00 p. m.
Sept. 8.....	0.53 inches	0.01 inch.
Sept. 9.....	3.48 inches	1.90 inches.
Sept. 10.....	1.46 inches	T. Total, 7.38 inches.

This shows a total amount of 6.84 inches for the 24 hours ending about 11:00 p. m., September 9th. If the

showers that occurred on the morning of the 8th are included, the total is 7.38 inches.

Records of the rainfall at San Antonio since 1885 show that only on one occasion has the 24-hour amount of September 9, 1921, been equaled or exceeded. This occurred on October 1-2, 1913, when 7.08 inches in 24 hours were recorded, and a destructive flood followed.

At the Weather Bureau station, near the center of the city, 1.46 inches of rain fell between 7:00 p. m. and 11:00 p. m., September 9. However, the rainfall increased rapidly north and west of this point until amounts of 3, 4, and 5 inches occurred during this same period of time at stations located from 2 to 5 miles distant.

On a map of the San Antonio River and its tributaries, accompanying this report, Fig. 1, are located 12 stations at which measured amounts of rain preceding the flood are shown. At five of these stations the precipitation was measured in regular 8-inch gages. See table 2, p. 526. At the remaining stations, including 9 others just outside limits of the map, improvised gages such as cans, barrels, and in one instance a wooden trough, were used. Allowance was made for sloping sides and rounded bottoms where these occurred. With but one exception each of the 21 gages was visited, inspected, and the measurements carefully checked.

In this connection the cooperation of the Engineering Department of the United States Army is kindly acknowl-

edged. Without their aid this report could not have been so complete.

**Reliability of rainfall measurements.**—At seven stations using regular rain gages the measured amounts are considered very reliable. The observers in some instances have kept rainfall records for many years. The nine

flood is approximately 75 square miles. In and adjacent to this drainage basin there were 12 measurements available and, with few exceptions, these measurements are in close accord. It is to be regretted that only at a few stations could amounts at different periods of the rain be obtained.

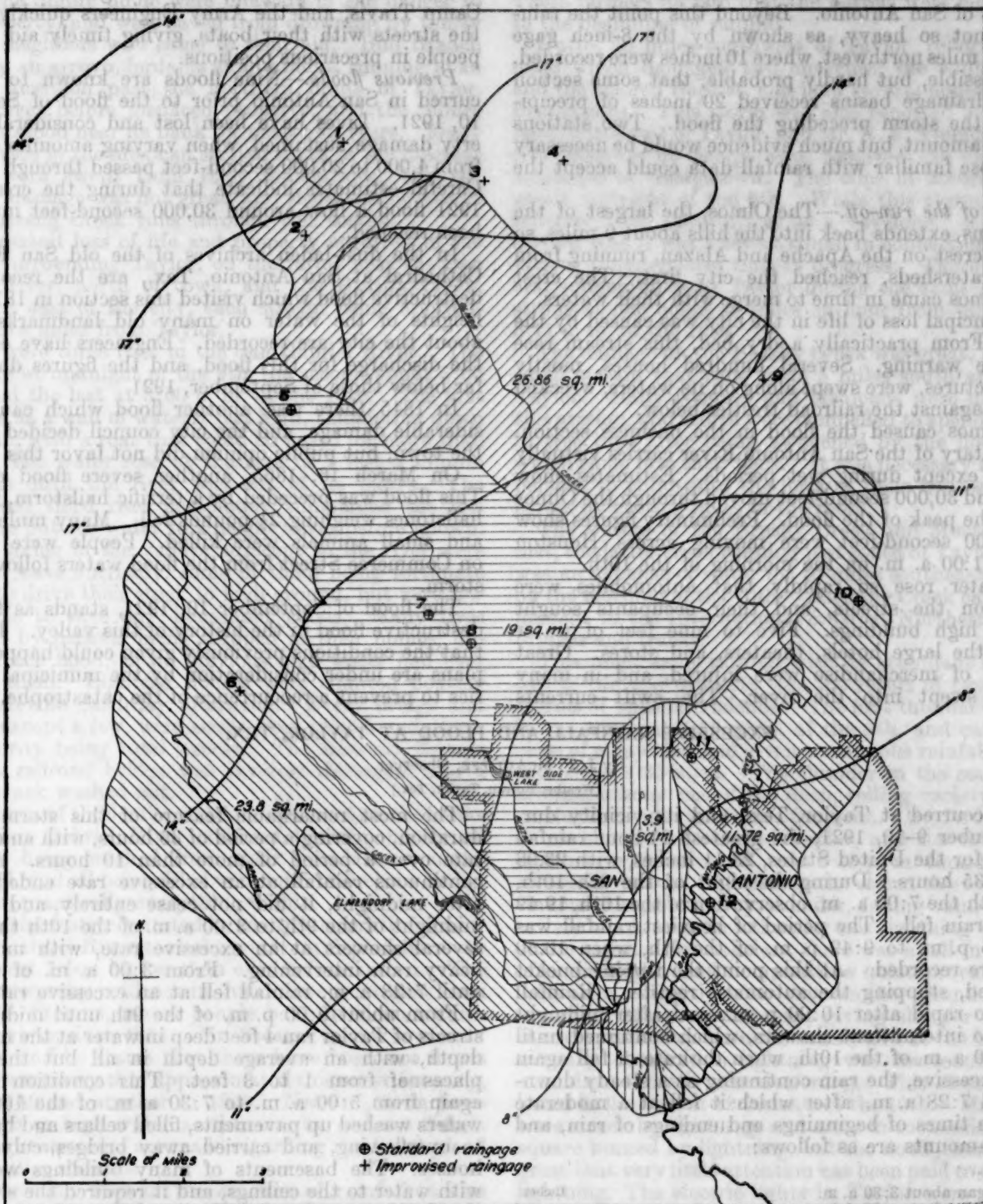


FIG. 1.—Drainage areas of the San Antonio River and its tributaries and the location of standard and improvised rain-gages. (See also Table 2, p. 526, this REVIEW.)

stations using improvised rain gages are given only approximate values in this report. However, the value of the data can not be based on the measurements of rain at any one locality, but on the large number of measurements taken over a relatively small area. The combined areas of the drainage basins responsible for this

**Heavy rains shown.**—Study of the accompanying map shows the rapid increase of rainfall north and west of the Weather Bureau station. Two miles north, 9.50 inches were recorded, with 3 inches after 7:00 p. m. on the 9th, as compared to 1.46 inches at the Weather Bureau station. Further study of the map brings out the fact that

approximately three miles north and west from the city more than 10 inches must have fallen. Between five and six miles north and west from the city's center the rainfall undoubtedly reached 14 inches over a considerable portion of the drainage areas. Nine stations show 15 inches or more.

The heaviest rainfall probably occurred 8 to 10 miles northwest of San Antonio. Beyond this point the rainfall was not so heavy, as shown by the 8-inch gage located 17 miles northwest, where 10 inches were recorded.

It is possible, but hardly probable, that some section of these drainage basins received 20 inches of precipitation in the storm preceding the flood. Two stations show this amount, but much evidence would be necessary before those familiar with rainfall data could accept the figures.

*Results of the run-off.*—The Olmos, the largest of the three basins, extends back into the hills about 9 miles, so the flood crest on the Apache and Alazan, running from shorter watersheds, reached the city first. The crest on the Olmos came in time to merge with their waters.

The principal loss of life in the city was caused by the Alazan. From practically a dry bed, this stream rose with little warning. Several hundred houses, mostly small structures, were swept along on its waters, wrecked and piled against the railroad trestles below.

The Olmos caused the flood in the business section. This tributary of the San Antonio River carries virtually no water except during wet periods. Estimates show that around 30,000 second-feet moved through the Olmos basin at the peak of the flood. Preliminary figures show that 21,000 second-feet were moving across Houston Street at 1:00 a. m. on the morning of the 10th.

The water rose so rapidly that automobiles were deserted on the streets, and their occupants sought safety in high buildings. Five to nine feet of water stood in the large hotels, theaters, and stores. Great quantities of merchandise were injured, and in many instances swept into the river. The swift currents

carried away miles of city pavements and injured or destroyed many bridges.

City water and power services were disabled and rescue work was handicapped by darkness. The loss of life undoubtedly would have been greater but for the proximity and efficient assistance rendered by the United States Army. Pontoons were brought in trucks from Camp Travis, and the Army Engineers quickly bridged the streets with their boats, giving timely aid to many people in precarious positions.

*Previous floods.*—Nine floods are known to have occurred in San Antonio prior to the flood of September 10, 1921. Lives have been lost and considerable property damage sustained, when varying amounts of water from 4,000 to 20,000 second-feet passed through the city. Careful estimates indicate that during the crest of the 1921 flood a flow around 30,000 second-feet must have been reached.

In the dust-laden archives of the old San Fernando Cathedral at San Antonio, Tex., are the records of a destructive flood which visited this section in 1819. The heights of the water on many old landmarks in and about the city are recorded. Engineers have estimated the discharge for this flood, and the figures do not fall far below those of September, 1921.

In 1845 there was another flood which caused considerable damage, and the city council decided to move the town, but public opinion did not favor this decision.

On March 16, 1865, another severe flood occurred. This flood was preceded by a terrific hailstorm, in which hailstones weighing 2½ pounds fell. Many mules, horses and small animals were killed. People were drowned on Commerce Street from the flood waters following this storm.

The flood of September 10, 1921, stands as the most destructive flood in the history of this valley. Realizing that the conditions previously given could happen again, plans are under consideration by the municipal authorities to prevent a recurrence of the catastrophe.

#### EXCESSIVE RAINFALL AND FLOOD AT TAYLOR, TEX.

By J. P. McAULIFFE, Observer.

[Weather Bureau, Taylor, Tex.]

There occurred at Taylor, Tex., and its vicinity during September 9–10, 1921, the greatest 24-hour rainfall on record for the United States, 23.11 inches, with 23.98 inches in 35 hours. During the night of the 9th–10th, ending with the 7:00 a. m. observation of the 10th, 19.49 inches of rain fell. The period of heaviest rainfall was from 6:45 p. m. to 9:42 p. m. of the 9th, when 10.50 inches were recorded. At this point the tipping bucket was flooded, stopping the automatic register. Rainfall was not so rapid after 10:00 p. m., and after midnight changed to intermittent showers, which continued until about 3:00 a. m. of the 10th, when the rate of fall again became excessive, the rain continuing as a steady down-pour until 7:28 a. m., after which it fell at a moderate rate. The times of beginnings and endings of rain, and the total amounts are as follows:

September 9:	
Rain began about 3:30 a. m.	Inches.
Total, midnight to midnight.....	16.11 <sup>1</sup>
September 10:	
Rain ended 2:30 p. m.	
Total midnight to midnight.....	7.87 <sup>1</sup>
Total.....	23.98
Total duration, 35 hours.	

<sup>1</sup> Partly estimated; tipping bucket stopped before midnight.

The most remarkable feature of this storm was its duration, covering a period of 35 hours, with an excessive rate over a period of more than 10 hours. Although continuous rainfall at an excessive rate ended shortly after midnight, it did not cease entirely, and from 12 midnight of the 9th to 3:00 a. m. of the 10th there were several showers at an excessive rate, with moderately heavy rain intervening. From 3:00 a. m. of the 10th until 7:28 a. m. rainfall fell at an excessive rate.

From about 9:00 p. m. of the 9th until midnight the streets of Taylor ran 4 feet deep in water at the maximum depth, with an average depth in all but the highest places of from 1 to 3 feet. This condition occurred again from 5:00 a. m. to 7:30 a. m. of the 10th. The waters washed up pavements, filled cellars and basements to overflowing, and carried away bridges, culverts, and houses. The basements of many buildings were filled with water to the ceilings, and it required the services of the city fire pumpers several days to pump the water out.

By 10:00 p. m. of the 9th the waters of Bull Branch had risen to unprecedented height, carrying away the home of J. W. Sillure, corner Porter and Eleventh Streets. The house lodged against a concrete bridge 300 feet east of its site, being practically a total wreck. The homes of B. A. Harcourt and Mrs. Dora Le Bleu, corner Wash-

burn and Eleventh, were swept into the stream and wrecked against the Missouri, Kansas & Texas railroad bridge half a mile farther east. The home of A. B. Norris on the same corner was lifted from its foundations and carried a short distance, but fortunately lodged in the mud and was but slightly damaged. The inmates of all but the Sillure home were unaware of the danger to their property, and were saved from drowning by timely work of neighbors who came to their aid. Bull Branch is usually an arroyo, fordable at any point, running in an easterly direction past the northern limits of Taylor. It has never before menaced property, and the Sillure home has stood near its bank for nearly 40 years. Many small houses in the Mexican section south of the business district were swept from their foundations, but the property damage was not great, and there was no loss of life. Mustang Creek runs through this section.

The greatest loss of life and property occurred in the country surrounding Taylor, on the farms near the San Gabriel River, north of town, and the Brushy Creek, south and east of the city, each stream being approximately five miles from Taylor.

There were three rises in the San Gabriel River. The first came at midnight of the 9th, the second about 5:00 a. m., and the last at 3:00 p. m. of the 10th. The first rise came as a wall of water 4 feet high, thundering down the stream with a roar that could be heard for more than a mile. The water rose at the rate of 2 feet a minute after this until the river was out of its banks. The second and third rises completely submerged the low lands, and put the water to a height never before known. Farmers living in the valleys adjacent to the river were forced to leave hurriedly, some of them being fortunate enough to drive their stock to high ground, but very few being able to save any household goods. Many lives were lost by persons being trapped in their homes, unaware of the flood, as no previous high water had ever reached them. Eighteen houses were counted floating past Circleville Saturday afternoon. Every bridge and culvert, except a few, were swept from their foundations, the majority being total wrecks. The Missouri, Kansas & Texas railroad bridge was severely damaged, and a mile of track washed out.

The towns of Circleville and Jonah, almost on the banks of the San Gabriel River, suffered heavily, nearly all buildings being washed from their foundations, many destroyed, and all being filled with mud to such an extent as to ruin practically everything within.

It is authoritatively stated by many farmers living near the San Gabriel River that the water on September 9-10 was at least 7 feet higher than ever before known. The most trustworthy evidence in this connection comes from Mr. H. T. Stearns, whose people have lived on a farm near the river since 1854. Mr. Stearns is now a man of 84 years, and he states that there have been two floods within his memory that approximated this one in severity, one in 1854 and another in 1868. None of them, however, gave as high water as this one by at least 7 feet. The same statements are made regarding the Brushy and other smaller streams.

To give some idea of the amount of rainfall in this vicinity not reported by the Weather Bureau, the statements of six intelligent and trustworthy farmers living north and east of Taylor should be cited. These farmers usually have barrels for hauling water when droughty conditions prevail. During the drought which preceded the downpour there was much hauling of water, consequently clean barrels were numerous. It is stated by these gentlemen that barrels on farms at different places measuring 36 inches high by 18 inches in diameter were

filled to overflowing on the morning of the 10th. It is certain that not more than 2 inches of water were in the barrels prior to the excessive rain, as this is the amount registered at the Weather Bureau station at that time. Allowing for all errors, it seems assured that some 30 inches of rain fell at many places in about 15 hours. These farmers declare that the barrels were empty prior to the beginning of rainfall.

Hutto, 10 miles southwest of Taylor, reported a tornado which damaged two churches, the white Baptist and the colored Baptist, and blew several houses off their foundations. This storm was also reported at Weir, 10 miles northwest of Taylor, and Mr. R. F. Young, cooperative observer at Georgetown, reported the same storm southeast of Georgetown. The time of occurrence was about midnight of the 9th. While this storm has been reported from these places as a "cyclone," it is almost certain that it was a severe squall in connection with the violent thunderstorm then in progress. There were several sudden gusts at Taylor during the same night, the strongest one being 31 miles an hour from the south at 3:11 a. m. of the 10th.

The damage on the Brushy Creek was great. This is a small stream that runs some 5 miles south and east of Taylor. Many Negroes and Mexicans were drowned in this section, and scores were compelled to spend the night in tree tops after being awakened by the flood waters which came into their beds. It was necessary for several persons to climb into the lofts of their houses and gain egress by cutting holes in the roofs.

The waters of the Brushy Creek and Mustang Creek met, the latter creek running just south of Taylor. There was an expanse of water for 10 miles southeast of Taylor on the morning of the 10th. Mustang Creek caused great damage to the International & Great Northern Railroad bridges and tracks.

This remarkable rainfall with its attendant floods and loss of life and property was the result of two thunderstorms of unusual violence. The first thunder was heard in the south at 4:19 p. m. of the 9th, and came at the close of a day that had given continuous rainfall at a slow rate since 3:30 a. m. The thunder in the south at the afternoon hour was of the deep, rolling variety, growing gradually louder and more frequent. By 7:00 p. m. the storm clouds had reached Taylor, and the thunder and lightning were incessant. At 9:45 p. m. thunder became unusually heavy. All during the storm there was a continuous roar, caused by thunder, falling rain, and more or less wind. Neither thunder nor lightning ceased the entire night. Nevertheless, there was a lull in the storm after midnight, and comparative quiet prevailed about 3:00 a. m. Shortly after this another thunderstorm as severe as the preceding one, giving sharper crashes of thunder, rolled up from the south, and at the hour of the morning observation lightning was incessant, and the attendant thunder was deafening. This storm was last heard in the west at 12:00 noon of the 10th. Many houses were struck by lightning, and areas in cotton fields 20 feet square burned by lightning, but the flood damage was so great that very little attention has been paid to damage by lightning. The electric lights in Taylor were put out of commission, and all telephone and telegraph service ceased.

It is a peculiar circumstance that while this downpour occurred from about San Antonio to above Cameron, a southwest-northeast distance of more than 200 miles, Elgin, just 18 miles south of Taylor, received less than 4 inches of rainfall.

In Taylor and vicinity the deaths resulting from the floods totaled 87, while the property losses amounted to about \$93,000.

## WIND VELOCITY AND RAIN FREQUENCY ON THE SOUTH TEXAS COAST.

By I. R. TANNEHILL, Meteorologist.

[Weather Bureau, Corpus Christi, Tex., Sept. 21, 1921.]

## SYNOPSIS.

The frequency of rainfall over southern Texas and particularly Corpus Christi is discussed with reference to the strength of the prevailing southeasterly wind. This section of the coast experiences daily in summer a fresh Gulf breeze having the characteristics of a monsoon. Its rainfall, however, is much less in summer than that of the upper Texas coast. It is shown that the increase in velocity of this prevailing wind in the forenoon is coincident with the interruption of the convectional process which indicates that the wind prevents local inequalities of temperature and, by mixing, interrupts convection already begun. It is further shown that this region bordering the Texas coast is dependent upon convection for its precipitation in summer and hence the strength of this monsoon is the important factor in rainfall forecasts for south Texas.

Over the lower coast section of Texas, rainfall in the months of June, July, and August averages much less than over the upper coast section. The prevailing winds in those months are onshore throughout the entire length of the coast line. Over the lower coast the daytime southeast breezes are persistent and there is an abundance of moisture in the air. Yet, precipitation here is small compared to that which occurs along sections of the Gulf coast to the north and east.

Rainfall in Texas decreases from the coast toward the interior, or, roughly, from east to west. This is easily understood as the Gulf is the chief source of moisture. It is not so readily understood why the rainfall decreases southward along the Texas coast, even though the lower portion lies farther to the west. Certainly the source of supply is as near at hand and the moist winds blow with even greater regularity. In fact, as is the rule in subtropical regions, the rainfall should increase toward the equator.

The normal rainfall for the months of June, July, and August, totals 18.24 inches at New Orleans, 13.74 inches at Galveston, and 6.68 inches for Corpus Christi. The relative dryness of the extreme southern portion of Texas is remarkable in view of the regularity and average velocity of the moisture laden winds that daily sweep over that entire section in summer.

During the 10 years, 1912 to 1921, inclusive, at Corpus Christi, the average hourly movement of the prevailing southeast wind in June, July, and August, has reached 19 miles at the hour of maximum movement and the five-minute maximum velocity frequently exceeds 30 miles per hour. This southeast monsoon increases in strength about sunrise and steadily continues to increase until about sunset and then slowly subsides during the night. This occurs day after day with monotonous regularity.

This southeasterly wind penetrates far into the interior and is felt as a hot, dry wind in southwestern and south-central counties. Its apparent dryness is due to increase of temperature in passing inland.

Practically all rains in the coast section of Texas in the months named are due to convection. Local inequalities of temperature cause vertical currents which build convection columns to altitudes sufficient for precipitation. Farther in the interior the convection columns must build upward to greater heights for condensation and precipitation on account of the lower relative humidity. There is insufficient slope for condensation by forced ascent; there is very little cyclonic influence; rarely is there an interruption of the prevailing wind or any mixing of winds of different temperatures; therefore, were it not for convection, the territory lying

westward from the lower Texas coast would receive little or no rainfall.

There have been many periods of prolonged drouth, when crops suffered in this section even though the Gulf winds blew with great regularity.

In the April, 1921, number of this REVIEW,<sup>1</sup> is discussed the relation between wind velocity and convective rains at Houston, Tex. It was there shown that on days with strong wind movement, convection is interrupted. In an effort to determine whether this southeast monsoon in the vicinity of Corpus Christi is of sufficient strength to prevent convection, the records of wind velocity and rain frequency have been compared. In Table 1 (not reproduced), the average hourly wind movement for each of the 24 hours, for the months of June, July, and August, covering the years, 1912 to 1921, inclusive, are shown, together with the hourly frequency of rain for each of the 24 hours for the same months during the same period.

Frequency of rain is taken as the total number of occurrences of precipitation of 0.01 inch or more in each hour for the months of June, July, and August during the period named.

An examination of this table shows clearly that the rainfall does not show the usual increase in frequency toward the hours after midday.<sup>2</sup> With the light winds of early morning rainfall becomes rapidly more frequent until there has been a considerable increase in wind velocity, when the frequency of rainfall remains stationary and then decreases rapidly. The minimum frequency of rainfall is coincident with the maximum wind, at an hour when convection, begun during the heat of the day, should continue with much activity.

Figure 1 shows this fact graphically. One sees at a glance that the fresh winds after midday have mixed the lower layer of the atmosphere thoroughly, smoothed out all inequalities of heating over the surface, and thus interrupted the convectional processes.

There is noticeable a certain lag in rain frequency as compared with wind velocity, which is to be expected. After the morning lull it takes a certain interval of time for the convectional columns to become established, and, once established, there is a strong tendency to continue despite the increase in wind velocity.

It is thus seen that, though the moisture is present over this region in great quantities, the only process which usually causes its precipitation is at times interrupted by increased movement of the wind. Turning again to the average rainfall values for the Gulf Coast during the summer months, we have New Orleans with 18.24 inches and an average hourly wind movement of 6 miles; Galveston with 13.74 inches and an average hourly wind movement of 9 miles; and Corpus Christi with 6.68 inches and an average hourly wind movement of 12 miles.

Rainfall records for southern Texas show a marked increase during the month of September, whereas the

<sup>1</sup> I. R. Tannehill. Correlation of wind velocity and convective rains at Houston, Tex. MO. WEATHER REV., April, 1921, 49: 204-205.

<sup>2</sup> E. D. Coberly. The hourly frequency of precipitation at New Orleans, La. MO. WEATHER REV., September, 1914, 42: 537-538. Here is shown graphically the increase in frequency of rainfall to be expected toward midday, with maximum shortly after noon. By referring to fig. 1, showing the frequency at Corpus Christi, it will be seen that, were it not for interruption of convection by wind movement, the frequency would continue to increase and the total summer rainfall at Corpus Christi would greatly exceed that received with such interruption.

wind movement is considerably less, though the southeasterly wind in September is yet strong. An examination of the records indicates that this unusual rainfall is due to cyclonic activity. For illustration: During the months of September in the last 10 years, 1911 to 1921, a total of 38.23 inches has been recorded at Corpus Christi. Of that amount 21.11 inches fell in five 24-hour periods, and during all of those periods the prevailing wind was from some point from east to north, indicating a deflection of the prevailing wind due to some tropical or other disturbance.

and evaporated. Hence wind movement is the important factor in the production of rainfall over this region. Therefore a further study into the causes of the monsoon in summer over the Texas coast, a determination of inequalities of temperature over extended land and water surfaces, and a study perhaps of upper air circulation and the relation between the strength of this current and the general pressure distribution may all yield important results in connection with forecasts of precipitation, and may make possible seasonal rain forecasts for the region bordering the Texas coast.

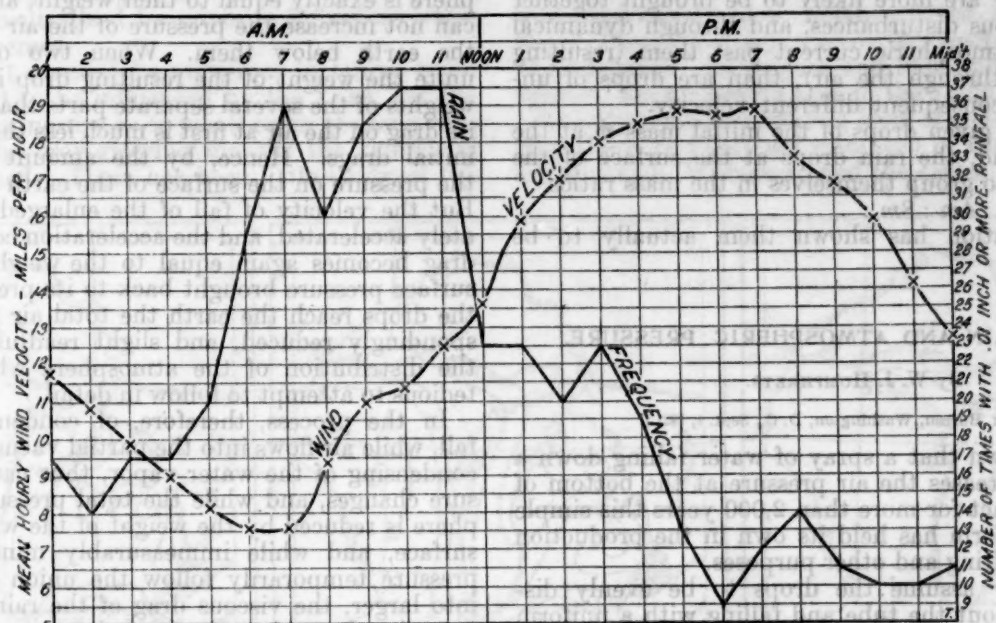


FIG. 1.—Relation between rain frequency and wind velocity on the South Texas Coast.

The southeasterly wind is so strong during the daytime that it obscures in the averages any temporary lull that aids convection and any delay of the increase of wind in the morning, hence no very clear relationship can be established between daily wind movements and frequency of rainy days. Yet this relationship over extended periods is consistent and noticeable. For example, in the very dry year, 1917, at Corpus Christi, with only 5.38 inches of rainfall, the total wind movement was 118,106 miles, whereas, in the wet year, 1919, with 34.31 inches, the total wind movement was 101,813. During the dry year, 1917, there was only 0.26 inch of rainfall in June with 12,685 miles of wind, while in the wet year, 1919, there were 6.24 inches of rain in July with a wind movement of 7,775. These departures from normal rainfall were not local. The drought of 1917 was marked over the entire State and all southern Texas received an excess of rainfall in 1919. It is therefore evident that changes in the velocity of wind in the summer monsoon affect not only the local rainfall but that of the coast section and much of the interior.

#### CONCLUSION.

Much of the coast section and interior adjoining the coast section of Texas is dependent upon convection for precipitation from its prevailing moisture bearing winds. When the southeasterly wind is strong, local inequalities of temperature at the surface are prevented and cloud masses, after formation, are mixed with surrounding air

#### THE MASS-GROUPING OF RAINDROPS.

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., Sept. 19, 1921.]

A number of years ago, Defant<sup>1</sup> made an extensive study of the masses of raindrops. Measurements of more than 10,000 drops, representing several different storms, showed that in each case the drops grouped themselves chiefly about the mass ratios 1:2:4:8:...

Recently Prof. T. Okada, of Japan, told me that he had repeated Defant's observations and that he had found the same results. Apparently, therefore, the observational evidence is quite sufficient to justify the tentative assumption that the phenomenon reported is practically universal, and to call for an effort to explain it.

It may be assumed (the justifying evidence need not be here repeated) that rain seldom occurs except in rising air. If this be true it follows that only those drops can fall from the cloud that are heavy enough to overcome the lift of the upward current, and that close to the under surface of the cloud the greatest number of drops actually descending are those that have substantially the minimum falling size. Let the mass of this minimum drop (minimum under the existing conditions) be  $m$ .

Now, drops of the same size, and under like conditions, fall with the same velocity, and, if once close together, continue close together for some time; whereas drops of

<sup>1</sup> Sitzungsberichte der K. Akad. der Wiss., Wien, p. 114: 585, 1905.

unequal size quickly separate. Clearly, then, drops of equal size are more likely to be brought together by fortuitous disturbances—gusts, turbulences, and the like—than are drops of unequal size.

Furthermore, as explained by Schmidt,<sup>2</sup> two drops falling side by side are slowly pushed together, just as passing boats are driven toward each other, with a force that depends in a known way (the full solution involves considerable mathematics) upon the velocity of fall, the size of the drops, and their distance apart.

Hence, because drops of the same size fall with the same speed they are more likely to be brought together through fortuitous disturbances, and through dynamical action of the atmospheric current past them (resulting from their fall through the air), than are drops of unequal size and consequent different velocity.

Finally, then, given drops of the initial mass  $m$  at the base of the cloud, the rain drops at the surface of the earth will tend to group themselves in the mass ratios

$$m : 2m : 4m : 8m : \dots$$

just as observation has shown them actually to be grouped.

#### FALLING RAIN AND ATMOSPHERIC PRESSURE.

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., Sept. 1, 1921.]

It is well known that a spray of water falling down a vertical pipe increases the air pressure at the bottom of that pipe. In fact for more than 2,000 years this simple device in some form has held its own in the production of blasts for smelting and other purposes.

For simplicity assume the drops to be evenly distributed throughout the tube and falling with a uniform velocity, a condition that well may be closely approached. Under such conditions the viscous drag of each drop on the air within the tube is equal exactly to its own weight. Hence when the blast is shut off, the pressure per unit area at the bottom of the tube is  $(w - a)/s$ , in which  $w$  is the weight of all the water in the column of spray,  $a$  the weight of the air displaced by this spray, and  $s$  the cross section of the tube. Clearly, then, with plenty of water and a high pipe almost any increase in pressure may be obtained.

<sup>2</sup> Met. Zeit., 25, p. 496, 1908.

Now, at the time of a heavy shower the column is half a mile high or more, and the water in it at any given instant sufficient, perhaps, to produce a rainfall an eighth of an inch deep. But the process of falling of these drops does not increase the barometric pressure, as one might infer from the action of the spray trompe that it would.

Before the rain begins the barometer measures the gravity pressure of all the atmosphere, including the water vapor, above it. Let now some of the vapor be condensed into droplets. So long as these are falling with uniform velocity their pull down on the atmosphere is exactly equal to their weight, and hence this pull can not increase the pressure of the air on the surface of the earth below them. When two or more droplets unite the weight of the resulting drop is the sum of the weights of the several separate parts that so united, while its drag on the air at first is much less than the sum of the initial drags. Hence, by the amount of this decrease the pressure on the surface of the earth is also decreased. But the velocity of fall of the enlarged drop is immediately accelerated, and the acceleration continues until the drag becomes again equal to the weight and hence the surface pressure brought back to its previous value. As the drops reach the earth the total air pressure is correspondingly reduced, and slight readjustments occur in the distribution of the atmosphere which it would be tedious to attempt to follow in detail.

In the process, therefore, of condensation and rainfall, while air flows into the partial vacuum caused by the condensing of the water vapor, thus causing slight pressure changes, and while the total pressure of the atmosphere is reduced by the weight of the water reaching the surface, and while immeasurably minute decreases in pressure temporarily follow the union of smaller drops into larger, the viscous drag of the rain on the air does not raise the surface pressure above its original value, as occurs at the bottom of a pipe in which spray is falling. In the case of rain there is either weight (while vapor) or equivalent drag (of the drops) on the atmosphere, so that transfer from the one to the other can not affect the surface pressure. In the case of the spray, on the other hand, the weight is not on the air, but on the feed tube, while the drag of the falling drops is on the air within the vertical pipe. In this case the transfer is not from weight on the air to drag on the air (an equal gain and loss) but from weight on an independent support to drag on the air, a net gain in respect to the atmospheric pressure.

#### DO THE GREAT LAKES DIMINISH RAINFALL IN THE CROP-GROWING SEASON?

By CYRUS H. ESHLEMAN, Meteorologist.

[Weather Bureau, Ludington, Mich., Sept. 19, 1921.]

##### SYNOPSIS.

During the severe drought in the early summer months of 1921, at Ludington, Mich., showers frequently seemed to avoid the shore of Lake Michigan. This led the writer to investigate the question whether or not the Lake actually causes a diminution in the normal amounts. The records show an area of maximum fall in the interior of extreme southern Michigan, in May, June, and July. In August and September the area is absent. Less rainfall occurs along the eastern than the western shore of Lake Michigan, and there is a maximum area in the interior of Wisconsin. Apparently the Lakes do cause some diminution. The probable cause is the Lake breezes during the middle of the day and the afternoon, strongest in May, June, and July, which promote circulation and have a lateral movement that prevents the ascending currents needed for local thunderstorms. In general, however, the monthly amounts are sufficient for agricultural interests.

Severe drought conditions prevailed during the early and middle crop-growing months of 1921, at Ludington, Mich., and in a number of counties of the vicinity, along the eastern shore of Lake Michigan. Conditions were

similar in many other sections of the United States, but as viewed locally, it appeared frequent rains were falling not far away. This was due partly to mere chance, several storm paths having been just to the north or south, but none for a number of weeks over the strip covering Ludington. However, in some degree, it seemed local causes were operating. Several good rains occurred just across the Lake to the west. Frequently clouds appeared in the west as if to produce rain, but were dissipated without doing so. Frequently local thunderstorms appeared to form just east of the station, and thunder was heard and showers were reported. On four successive days in one case, heavy clouds were observed in the middle of the day in the east, while overhead, and in the west, north, and south the sky was cloudless.

The writer has been stationed along this shore of Lake Michigan about 11 years, approximately half of the time

at Grand Haven and the other half at Ludington. He had previously thought that the Lake does not materially diminish the amount of rainfall; that while it might do so in some instances, these are compensated by opposite effects when the winds in the same month are from the other directions. He had often seen thunderstorms come in from the Lake and had not noticed that they were weakened or dissipated. It was clearly recognized that in months when the Lake is warmer than the land, precipitation is usually slow to begin with offshore winds, the reason being that the wind is warmed as it approaches the Lake; but it was thought, as stated above, that the effect is largely neutralized by opposite influences when the winds are reversed.

But in the 1921 season, the numerous instances when showers appeared to be influenced by the Lake, led the writer to begin an inquiry as to whether, in the long run, during any of the crop-growing months the rainfall is actually diminished. There has been little study of the

result of the differences in periods, and the normals as used probably show quite accurately the amounts as caught by the gages. Whether the catch of the gages is affected by altitude or wind velocity, or other causes, will be considered after the examination of the data.

In figure 1 is shown the total for the five-month period May to September, inclusive; the total for May, June, and July; and the total for August and September.

It is readily seen that for the three months, May, June, and July, there is an area of maximum rainfall in the interior of extreme southern Michigan, whence there is a decrease to the east, west, and north, though the decrease is comparatively slow northeastward toward Saginaw Bay. There is perhaps a secondary maximum to the east of Ludington. In August and September, according to figure 1, the maximum area in the south is absent.

The Michigan distribution from May to September and May, June, and July are embraced in a larger area covering Michigan, Wisconsin, and the Lakes.

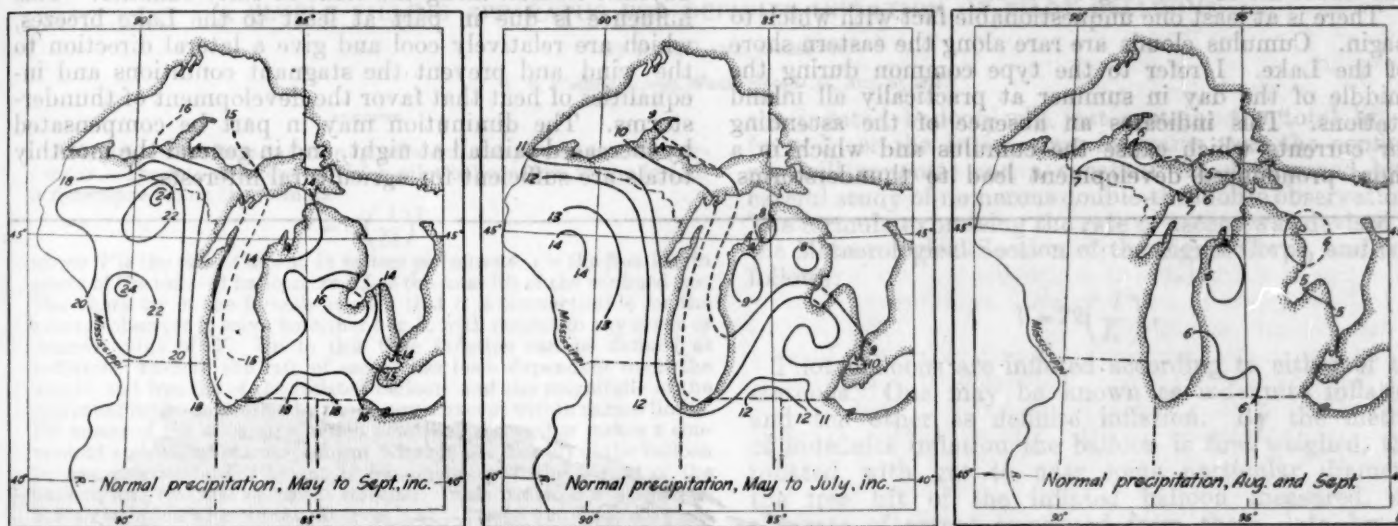


FIG. 1.—Distribution of precipitation for various periods for Michigan, Wisconsin and the Lakes.

winter precipitation, since for agricultural interests the amounts then are not important, and since, also, there are many complications connected with snowfall measurements that make the problem perplexing, if not at present insoluble.

Several years ago Mr. Eric R. Miller, of the Madison, Wis., station, studied the effects of the Lakes on the climate of Wisconsin. The results are given in a paper read at the second Pan-American Congress, 1915-1916, and published in the *Proceedings*, Volume II, section II, page 189. One of the conclusions drawn was that decidedly less rainfall occurs near the Lakes in summer, the excess in the interior of the State for the period April to September, inclusive, being 12 inches, or 86 per cent of the amount falling along the Lakes.

In order to learn the distribution in Michigan the present writer has charted the normal amounts as given in the monthly climatological data for all the regular and cooperative stations. The periods of observation range from 20 to 50 years or more. In general, the periods are longest for the shore stations, owing to the fact that most of the regular stations are there and were earliest established. But there are numerous long-period cooperative records in the interior of the middle and southern portions of the lower peninsula. In the interior of the northern portion and in the interior of the upper peninsula the records are comparatively brief and meager. But there appear to be no radical inconsistencies as a

A comparison of the normals for the stations immediately along the west and east shores of Lake Michigan is interesting and significant.

Tables 1 and 2 give the figures for six stations along the west shore and six in the same latitude along the east shore.

TABLE 1.—Comparison of normal rainfall along west and east shores of Lake Michigan for May, June, and July.

Wisconsin stations:	Inches.	Michigan stations:	Inches.
Green Bay.....	10.63	Frankfort.....	8.67
Manitowoc.....	10.80	Manistee.....	8.85
Sheboygan.....	10.33	Ludington.....	8.84
Port Washington.....	10.95	Hart.....	9.11
Milwaukee.....	10.11	Muskegon.....	8.56
Racine.....	10.50	Grand Haven.....	8.43
Total.....	63.32	Total.....	52.46

Seventeen per cent less along east shore.

TABLE 2.—Comparison for August and September.

Wisconsin stations:	Inches.	Michigan stations:	Inches.
Green Bay.....	6.07	Frankfort.....	5.38
Manitowoc.....	5.10	Manistee.....	5.52
Sheboygan.....	5.99	Ludington.....	5.35
Port Washington.....	6.08	Hart.....	5.70
Milwaukee.....	5.80	Muskegon.....	5.49
Racine.....	6.67	Grand Haven.....	5.76
Total.....	35.71	Total.....	33.20

Seven per cent less along east shore.

Let us now inquire briefly as to the causes of the distribution shown by these figures and tables.

Part of the northward decrease through the lower peninsula of Michigan may be due to increasing distance from the Atlantic Ocean and the Gulf of Mexico. A fraction of the excess in the southern interior of the State and of the slight excess to the east of Ludington may be due to the altitude, which is 300 feet or more above that along the Lakes; but if this influence were important it should be apparent also in August and September. There may be a percentage of error due to the stronger wind velocities at the shore stations, which cause eddies at the mouth of the rain-gage and thus reduce the catch; but if this error were large it should operate no less in August and September, when the average daily velocities are practically the same. Other sources of error and other causes of the conditions might be suggested. Nevertheless, the evidence seems strong that somewhat less rain falls along the Lakes and that the Lakes are in some degree the cause.

There is at least one unquestionable fact with which to begin. Cumulus clouds are rare along the eastern shore of the Lake. I refer to the type common during the middle of the day in summer at practically all inland stations. This indicates an absence of the ascending air currents which cause the cumulus and which in a more pronounced development lead to thunderstorms.

August and September, it may be stated, because the Lakes have then become warmer and the breezes weaker.

Another proof that some influence operates against daytime rainfall is the fact that more than 50 per cent in the summer season falls in the night, from 7 p. m. to 7 a. m.<sup>1</sup> The writer has computed the amounts at Ludington for the past nine years since the regular observing station was established, and finds that 61 per cent of the rainfall from May to September, inclusive, has occurred between 7 p. m. and 7 a. m., leaving only 39 per cent for the other 12 hours. However, it is possible that conditions along the Lake increase the night rainfall, thus in part making up the deficiency.

#### CONCLUSION.

Recognizing the possibilities of error and disclaiming any desire to dogmatize, the writer is nevertheless inclined to advance the view that the Lakes diminish the daytime rainfall along the Lake in early summer. This influence is due in part at least to the Lake breezes, which are relatively cool and give a lateral direction to the wind and prevent the stagnant conditions and inequalities of heat that favor the development of thunderstorms. The diminution may in part be compensated by increased rainfall at night, and in general the monthly totals are sufficient for agricultural interests.

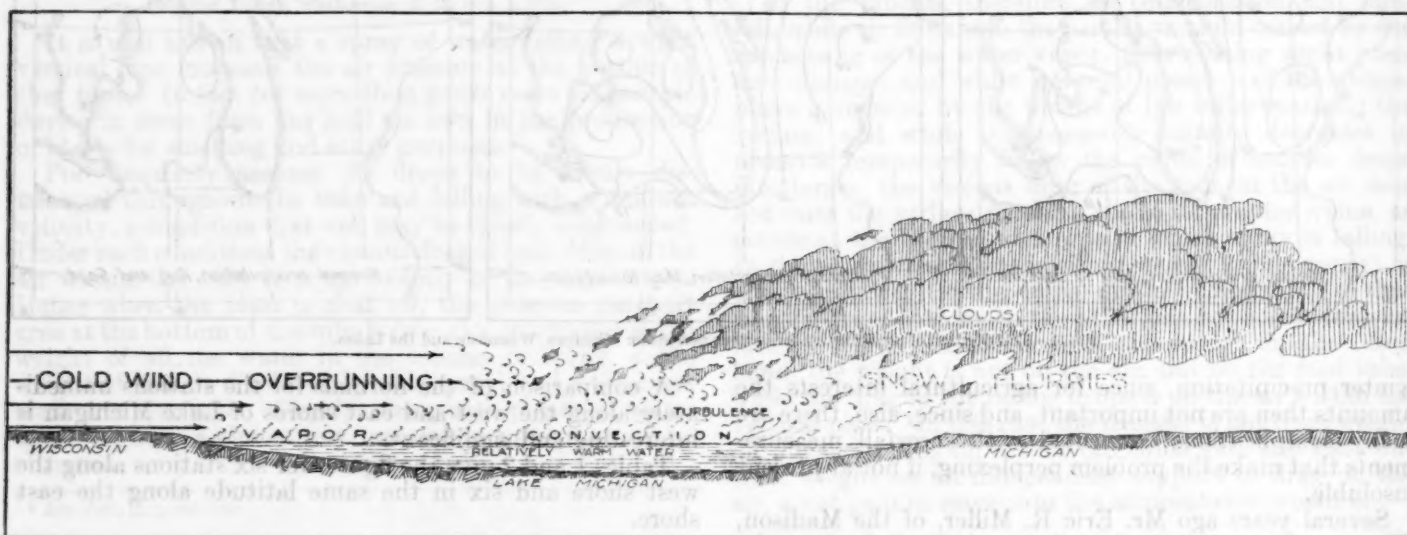


FIG. 1.—Formation of clouds and fog over Lake Michigan.

The absence of the ascending currents is evidently due to the Lake breezes, which prevail during that time of the day, and, coming in to the shore, give the wind a strong lateral direction. This constant circulation of relatively cool air prevents the stagnant conditions and inequalities of air temperatures that are necessary for thunderstorm development. And, since thunderstorms usually travel in an easterly direction, a diminished frequency would be felt to some distance inland. This circulation due to Lake breezes may in some degree cover the whole northern end of the lower peninsula and thus prevent the greater rainfall that occurs in the interior of the southern portion which is less surrounded by water. The fact that more rainfall occurs along the west shore in Wisconsin may be accounted for by the statement that thunderstorms originating far inland to the westward would proceed almost, if not entirely, to the Lake before encountering the unfavorable tendencies. The advantage for interior counties in Michigan disappears in

#### SNOW FLURRIES ALONG THE EASTERN SHORE OF LAKE MICHIGAN.

The familiar phenomenon of snow flurries with westerly winds, especially during the early part of winter, at Grand Haven and Ludington along the eastern shore of Lake Michigan, and possibly as far inland as Grand Rapids, while clear weather prevails at Chicago, Milwaukee, and Green Bay on the western shore, prompted the writer to ascertain, if possible, how far back over Lake Michigan these snow flurries extend, as well as the cause of the cloudiness and snowfall. It was thought that the vessel masters of the Pere Marquette car ferries plying between Ludington, Mich., and Milwaukee and Manitowoc, Wis., should be able to furnish quite definite information as to the extent of these flurries over the lake. Accordingly, request was made of the official in

<sup>1</sup> Humphreys, W. J.: On the differences between summer daytime and night-time precipitation in the United States. *MO. WEATHER REV.*, June, 1921, 49: 350-351.

charge at Milwaukee to obtain, if possible, the desired information. Replies to his letter of inquiry were received from Masters Bahle, Robertson, and Van Dyke, that of Master Bahle<sup>1</sup> being given below:

With the wind west and the weather clear we may have vapor or steam, as we call it, part way or all the way across the lake. All depends on the difference in the temperature of the water and the air. During the early part of winter, say in December, when the water is not the coldest, the weather will moderate as we reach the east shore or as we near the east shore and this will cause the steam (fog) to rise off the water entirely in clouds and then snow may fall. I have seen this anywhere from the middle of the lake to the east shore. Later in the winter when the water becomes real cold and the air temperature say about 15° below zero on the west shore, the steam (fog) may reach the east shore and snow there also, the snow not extending out in the lake more than 2 or 3 miles. In other words, it does not snow when the steam (fog) makes. It starts to snow where the steam (fog) stops making and starts to rise in clouds entirely away from the water.

Masters Robertson and Van Dyke both wrote that steam or fog rising on the western shore of the lake means snow on the eastern shore, and that these flurries

extend back 10 to 20 miles from the eastern shore, as a rule.

The cold air from the west reaches Lake Michigan with a temperature considerably below freezing and sweeps out over the lake, the water of which has a temperature of nearly 40° early in December and approximately 32° during January and February. It appears, therefore, that there is a layer of warmer air immediately over the lake under these conditions, being necessarily quite shallow along the western shore and increasing in depth toward the east, and that convectional currents and turbulence set in, manifesting themselves in the form of vapor near the western shore, in the formation of clouds farther out in the lake and, eventually, precipitation in the form of snow flurries where convection and turbulence are sufficient to produce it.

The accompanying illustration by Mr. W. P. Day (p. 502) shows graphically the manner in which clouds and precipitation are brought about.—C. L. Mitchell.

#### A SIMPLE FILLING APPARATUS FOR DEFINITE INFLATION OF PILOT BALLOONS.

By R. C. LANE, Observer.

[U. S. Weather Bureau, Washington, D. C., Aug. 30, 1921.]

##### SYNOPSIS.

*Indefinite and definite inflation of pilot balloons for aerological observations.*—The rate of ascent at which pilot balloons rise in the free air is determined from the formula

$$V = 72 \left( \frac{l}{L} \right)^{\frac{1}{2}},$$

where  $V$  is the rate of ascent in meters per minute,  $l$  is the free lift in grams of the inflated balloon, and  $L$  is the total lift of the confined gas. The character of the formula is such that it is impracticable for the average observer to solve for either  $l$  or  $L$ , with respect to any given or desired value of  $V$ . Up to this time inflation can be defined as *indefinite*, wherein the rate of ascent has been dependent upon the weight and free lift of the inflated balloon, and the magnitude of the rate could not be controlled by the observer except within narrow limits. By means of the apparatus herein described the author makes a convenient and valuable transposition, wherein the free lift of the balloon for any desired rate of ascent is dependent upon the weight of the balloon and the rate of ascent selected. This provides a method of *definite* inflation wherein the observer is able to select any rate of ascent suitable to the fancy or to the current meteorological conditions, and inflate the balloon accordingly. The process of inflation is thereby resolved to the equivalent mechanical operation of the method, earlier used.

Since the earlier stages of pilot balloon observation work, the need of some efficient apparatus for the inflation of balloons to a particular rate of ascent has been generally felt, and this need has increased with the rapid development of observation work. The apparatus here disclosed has been devised after considerable study of various methods and after much experimental work. The simplicity of the arrangement and the purely mechanical manipulation of the apparatus in practice, with the small amount of machine work necessary in construction, should tend toward the general use of such an apparatus in observations with pilot balloons.

At present, balloons, when inflated with hydrogen, are assumed to rise with a nearly constant rate of ascent. In the United States, the rate  $v$ , at which they are assumed to ascend, is computed by a formula which takes into account the weight  $w$ , in grams, of a rubber balloon expelled of air; the free lift  $l$ , or the mass in grams that

the inflated balloon will just sustain; the total lift  $L$ , ( $w + l$ ), or the entire mass in grams that the confined gas will support; and a constant 72, determined by a careful study of numerous double-theodolite observations. The formula expressing the rate of ascent was devised by the Meteorological Section of the Signal Corps, and is as follows:

$$V = 72 \left( \frac{l}{L} \right)^{\frac{1}{2}} \quad (1)$$

Pilot balloons are inflated according to either of two methods. One may be known as *indefinite* inflation, and the other as *definite* inflation. By the method of *indefinite* inflation the balloon is first weighed, then inflated with gas to near some particular diameter, the free lift of the inflated balloon measured, and the rate of ascent computed from these data by the formula. The resulting rate of ascent may be any odd value. By the method of *definite* inflation, some convenient rate of ascent is determined, the balloon is then weighed, the amount of free lift necessary for that particular rate of ascent and weight is then determined, and the balloon inflated accordingly.

Inflation by the *definite* method is superior to the *indefinite* since it enables one to inflate to any desired rate of ascent. In view of this fact, a rate of ascent of 200 m./min. or any other rate in which the successive multiples end in one or more zeros, will materially increase the ease, speed, and accuracy of computation in determining the horizontal distance of the balloon from the observation point. Whether the computation be made by slide rule or by graphical means, the above statement is equally true. As an illustration, suppose the altitude of a balloon at the end of some particular minute when inflated by the *indefinite* method is 3151 meters, and by *definite* inflation we have an altitude of 3300 meters for the corresponding minute. The number 3300 can be set more quickly and accurately on the slide rule than can the number 3151. Experience has proved that the *definite* inflation method will not only insure accuracy and speed, but will truly permit a higher quality of work in general.

*Definite* inflation is more difficult to attain than *indefinite* inflation and is practically impossible without the aid of some specially designed apparatus. The character of the formula by which the rate of ascent is computed,

<sup>1</sup> The following interpretation is put upon the letter reproduced above: In December when the water is warmer than the overlying air surface air coming from the west becomes warmer as it passes over the lake and gains distance toward the east until finally it reaches a point over the lake when the contrast in temperature between air and water is not sufficient to form fog. By this time, however, vertical convection has carried the moisture of the fog high enough to be condensed as snow and this is probably the explanation of the statement—it does not snow when fog makes; it starts to snow when the fog stops making and starts to rise in clouds. Evidently there are times also when the fog extends from shore to shore; at these times there may be snow on the east shore.—Editor.

is such that the free lift  $l$ , can be determined only by a laborious method too long and deeply involved to permit of rapid application. Therefore, tables for selected rates of ascent have been computed and only recently published as Table 28, in *Instructions for Aerological Observers*, by the United States Weather Bureau.

The equipment necessary for indefinite inflation consists of little else than a hydrogen line terminating in a short length of soft and rather pliable rubber tubing leading to a suitable nozzle upon which the balloons may be secured, all adapted to a delicate balance, and weights with which to determine the weight,  $w$ , and lifting power,  $l$ , of the balloon. The apparatus for definite inflation requires but little more. However, some alteration in the equipment and a complete reversal of the operation are necessary. The hydrogen line and nozzle must be carried to and installed upon the balance. Extreme care must be given to this installation so that the sensitivity of the balance may not be interfered with. An efficient filling apparatus must be both sensitive and accurate.

The function of such an apparatus is to attain the exact amount of free lift for a balloon of given weight so that it may ascend at some predetermined rate. The amount of free lift required corresponding to weight and rate of ascent can be found in Table 28, *Instructions for Aerological Observers*. The remaining problem then is to bring the inflation to that point, and is accomplished by securing the balloon to the nozzle on one pan of the balance, establishing equilibrium of the beam system or weighing of the balloon, applying a definite load to the same pan of the balance to which the balloon is secured, and allowing the gas to flow until equilibrium of beam system is again established.

The amount of necessary alterations of the balance will depend upon the type of balance used in the regular observation work. The type of balance used in pilot balloon observations by the United States Weather Bureau is supplied by the Central Scientific Co. of Chicago, Ill., and is catalogued as No. 652, "Dispensing and Solution Scale." The method and apparatus developed in this paper require very little alteration of that balance, and may be grouped as (a) hydrogen line support, (b) nozzle assembly, (c) free lift scale bar.

The hydrogen line support consists of one end of the main hydrogen line rigidly secured to the balance frame so that it does not detract from the sensitivity of the beam system. The nozzle assembly consists of a suitable terminal of hydrogen line affixed to the left hand pan of the balance, upon which the balloon may be placed for inflation. The free-lift scale bar consists of a carefully graduated bar, carrying a 20 gram rider, rigidly fixed to, and parallel with the beam system of the balance. In conjunction with the latter, provision is made for the application of a weight of a certain mass to the nozzle end of the beam system.

The principle of the filling apparatus under discussion is founded upon the equivalent moments of force on either side of the fulcrum of a simple lever. Suppose the length of the arms of the balance beam to be  $a$  and  $b$ , Fig. 1. Now, since a balloon inflated with hydrogen will exert a lifting force,  $l$  (free lift), let us apply a weight,  $m$ , of some convenient and known mass to the same arm of the system. By reference to Table 28, *Instructions for Aerological Observers*, it will be seen that the element  $l$ , will vary for the ascensional rate depending upon the weight of the balloon that is being inflated, and therefore, the difference between the lifting force,  $l$ , and the applied mass,  $m$ , will also vary. Let this difference be known as  $r$ , the amount of variation to be accounted for

by the free-lift scale bar and rider. Both  $l$ , and  $m$ , act through the arm  $a$  and opposite to each other; the difference between their working forces measures the magnitude of  $r$ . Now, by the laws of the simple lever.

$$(m-l)a = rb \quad (2)$$

In the balance used,  $a$  and  $b$  are equal and might be factored out of the equation, but the final development of the apparatus requires that they be retained. The element  $l$  is found in Table 28, already mentioned; and  $m$  will be any convenient weight, remaining the same for any one rate of ascent; it may be greater or less in mass than  $l$ .

To inflate a 15-gram balloon to ascend at a rate of 200 m./min. we require a free lift,  $l$ , Table 28, *Instructions for Aerological Observers*, of 161.1 grams. The weight of  $m$ , designed for the 200 m./min. rate is 200 grams. The difference between these forces amounts to 38.9 grams and acts through a distance of 10 centimeters from the fulcrum. Substituting these values in formula (2), it is obvious that 389.0 gram-centimeters of force must be added to the arm  $b$  in order to establish equilibrium throughout the system. With an unaltered balance it would be necessary to place a mass of 38.9 grams upon the pan at the end of arm  $b$ , but by the method under

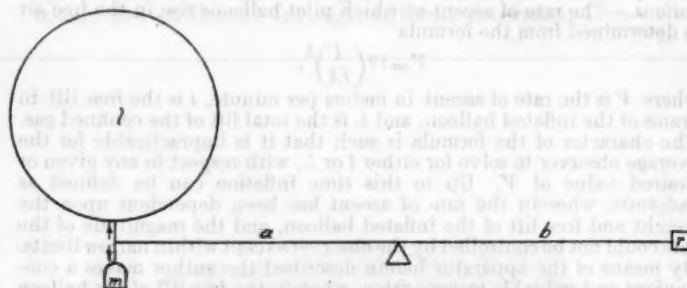


Fig. 1.—Schematic drawing showing the principle of the simple lever as applied to the free lift and rider adjustments used in overcoming the moment of a constant mass.

development, the entire operation is mechanical and no attention need be given to the deduction of differences, nor to the selection of weight to satisfy the force  $r$ ; thus two sources of error are eliminated. In this respect the apparatus is automatic.

Figure 2 shows the arrangement of the apparatus. The balance in standard use is provided with a hydrogen line support inserted through a hole in the base casting. The assembled support consists of a piece of  $\frac{1}{4}$ -inch brass rod 7 inches long, with  $\frac{3}{8}$ -inch pipe thread on one end. On this threaded end of support is screwed a  $\frac{3}{8}$ -inch brass T, carrying a short piece of  $\frac{3}{8}$ -inch pipe on one side, and a three-way stop cock and reducer on the other. The post of the assembly is inserted in the base of the balance and secured by means of a set screw.

The nozzle assembly consists of a specially designed brass L. One arm of the L is extended through the bend to terminate in a screw and nut. On the opposite end is placed a wooden nozzle about 2 inches in diameter on which the balloon is secured. The remaining arm of the L is fitted with a reducer. The threaded end of assembly is then passed through a hole in the center of the left-hand scale pan and secured by aid of the nut. The reduced portions of the L and the three-way stop cock are then connected with a 15-inch piece of  $\frac{1}{4}$ -inch soft rubber tubing.

The free-lift scale bar consists of a brass bar  $16\frac{1}{2}$ " by  $\frac{3}{4}$ " by  $\frac{1}{4}$ ", carefully milled and graduated, and carries a 20-gram rider. Two holes  $\frac{1}{4}$  inch and countersunk are

drilled through the bar 3 inches on either side from the mid-point for securing the bar to the beam system of the balance in place of the 10-gram graduated beam with which the balance is originally equipped. Associated with the arrangement of this bar may be considered the support for the weight,  $m$ , for the magnitude of the weight will affect the position of the graduations on the bar. This support may consist of a ring or hook on the underside of and in line with the knife edge of the left-hand scale pan; or the supporting hook may be entirely dispensed with and the weight  $m$  so fashioned that when it is placed on the upper side and in the center of the pan it will fit closely about the stem of the nozzle assembly.

The mass of the weight,  $m$ , to be used for any one particular rate of ascent should be near the mean of the free lifts for the maximum and minimum weights of balloons that are likely to be inflated to that rate of ascent. With a rate of 200 m./min. for weights of balloons from 15 grams to 80 grams, inclusive, it was found that a mass of 200 grams was best adapted for the weight  $m$ . For inflations to a rate of 180 m./min. for the limits of weight from 15 to 80 grams, a mass of 140 grams seems best for the weight,  $m$ . The free lift scale for 200 m./min. and 180 m./min. rates have been graduated accordingly. Using weights of those magnitudes enables us to confine the length of scale bars to 16 inches and 14 inches, respectively, with about half of the graduations on either side of the mid-point of the bar. It is hardly practicable to use a weight of 200 grams for the 180 m./min. rate for the necessary length of the bar would be greatly increased; a bar 37 inches long would be required.

The positions for each graduation on the scale bar were determined by a special method of computation. For the various weights of a balloon from 15 to 80 grams, inclusive, the amount of free lift necessary to give the particular rate of ascent was worked out to the fractional part of a gram in the third place. These data after reducing and checking gave the result under  $e$  of the accompanying table. Since weights of 140 grams and 200 grams had been selected as the mass of  $m$ , for rates of ascent of 180 and 200 m./min., respectively, and since these weights were always to be used for those particular rates of ascent, there would be a difference between these masses and the free lift for the various weights of balloons. The third and seventh columns, headed 10 (140-l) and 10 (200-l) give these differences reduced to gram-centimeters of force for the 180 and the 200 rate, respectively.

It was decided that a 20-gram rider was the most convenient size to be used since the scale graduations could then be included within the extremities of a bar 16½ inches long with an average distance of 11.0 millimeters between each gram division. Therefore, to determine the position on the scale bar for the rider, so that it would overcome the difference in moments of force, it would be necessary to divide that number into the difference. Substituting these values in formula (2), and solving for  $b$  we obtain the distance from the mid-point of free lift scale bar that the rider must be placed to overcome the difference in moments of force. The last two columns of the table under each rate of 180 m./min. and 200 m./min. give the position or distances of graduates from the mid point of bar for the corresponding weights of balloons. These distances are given in the table both in millimeters and in inches. Whether the graduations will be placed to the right or

to the left of the mid-point of the bar is determined by the character of the difference in the moments of force. If its moments of the free lift are less than the moments of the weight  $m$ , then the difference in moments between these two must be added to the right hand pan to establish equilibrium when the balloon is inflated to that lift; again if the moments of the free lift are more than the moments of the weight  $m$ , the applied weight  $m$  will be insufficient to measure that amount of free lift and the difference in moments must be added to the left hand pan of the balance. Therefore, let the minus signs of Table 1, indicate values to the left of the mid point of scale bar. The free lift scale bar in figure 2 is graduated for an ascensional rate of 200 m./min. Table 1 gives the data for graduating the free-lift scale bar for rates of 180 m./min. and 200 m./min. in both English and metric units.

TABLE 1.—Showing distance of graduations from mid point of free-lift scale bar, for ascensional rates of 180 and 200 meters per minute.

Weight (g.)	Rate 180 meters per minute.				Rate 200 meters per minute.			
	Free lift (l)	10 (140-l)	Position of rider.		Free lift (l)	10 (200-l)	Position of rider.	
g.	g.	g.-cm.	mm.	in.	g.	g.-cm.	mm.	in.
15.	105.96	340.4	170.20	6.70	161.09	380.1	194.55	7.35
16.	107.32	326.5	163.40	6.43	162.73	372.7	186.23	7.35
17.	108.70	313.0	156.50	6.16	164.30	357.0	178.50	7.04
18.	110.06	299.4	149.70	5.90	165.77	342.3	171.15	6.74
19.	111.37	286.3	143.15	5.64	167.27	325.3	162.65	6.45
20.	112.70	273.0	136.50	5.38	168.69	313.1	156.55	6.16
21.	113.95	260.5	130.25	5.13	170.23	297.7	148.85	5.86
22.	115.19	248.1	124.05	4.88	171.72	282.8	141.40	5.57
23.	116.45	235.5	117.75	4.64	173.17	268.3	134.15	5.29
24.	117.71	222.9	111.45	4.39	174.57	254.3	127.15	5.01
25.	119.03	209.7	104.85	4.14	175.87	241.3	120.65	4.74
26.	120.22	197.8	98.90	3.89	177.35	226.5	113.25	4.49
27.	121.43	185.7	92.85	3.65	178.70	213.0	106.50	4.19
28.	122.66	173.4	86.70	3.41	180.07	199.3	99.65	3.92
29.	123.86	161.4	80.70	3.18	181.43	185.7	92.85	3.66
30.	125.01	149.9	74.95	2.95	182.72	172.8	86.40	3.40
31.	126.18	138.2	69.10	2.72	184.07	159.3	79.65	3.14
32.	127.33	126.7	63.25	2.49	185.38	146.2	73.10	2.88
33.	128.45	115.5	57.75	2.27	186.62	133.8	66.90	2.63
34.	129.57	104.3	52.15	2.05	187.93	120.7	60.35	2.37
35.	130.69	93.1	46.55	1.83	189.28	107.2	53.60	2.11
36.	131.77	82.3	41.15	1.62	190.60	94.0	47.00	1.85
37.	132.86	71.4	35.70	1.41	191.88	81.2	40.60	1.60
38.	133.97	60.3	30.15	1.19	193.13	68.7	34.35	1.35
39.	135.06	49.4	24.70	.98	194.38	56.2	28.60	1.11
40.	136.10	39.0	19.50	.77	195.60	44.0	22.00	.87
41.	137.17	28.3	14.15	.56	196.88	31.2	15.60	.62
42.	138.24	17.6	8.80	.35	198.11	18.9	9.45	.37
43.	139.23	7.7	3.85	.15	199.33	6.7	3.35	.13
44.	140.30	-3.0	-1.50	-.06	200.51	-5.1	-2.55	-.10
45.	141.31	-13.1	-6.55	-.26	201.69	-16.9	-8.45	-.33
46.	142.32	-23.2	-11.60	-.46	202.88	-28.8	-14.40	-.56
47.	143.33	-33.3	-16.65	-.66	204.03	-40.3	-20.15	-.79
48.	144.35	-43.5	-21.75	-.86	205.20	-52.0	-26.00	-1.02
49.	145.36	-53.6	-26.30	-1.05	206.39	-63.9	-31.95	-1.26
50.	146.35	-63.5	-31.75	-1.25	207.59	-75.9	-37.95	-1.49
51.	147.31	-73.1	-36.55	-1.44	208.76	-87.6	-43.90	-1.72
52.	148.31	-83.1	-41.55	-1.64	209.92	-99.2	-49.60	-1.95
53.	149.30	-93.0	-46.50	-1.83	211.07	-110.7	-55.35	-2.18
54.	150.26	-102.6	-51.30	-2.03	212.19	-121.9	-60.95	-2.40
55.	151.21	-112.1	-56.05	-2.22	213.32	-133.2	-66.60	-2.62
56.	152.18	-121.8	-60.90	-2.40	214.43	-144.3	-72.15	-2.84
57.	153.13	-131.3	-65.65	-2.58	215.54	-155.4	-77.70	-3.06
58.	154.06	-140.6	-70.30	-2.76	216.64	-166.4	-83.20	-3.28
59.	155.01	-150.1	-75.05	-2.94	217.75	-177.5	-88.75	-3.49
60.	155.91	-159.1	-79.55	-3.13	218.87	-188.7	-94.35	-3.71
61.	156.83	-168.3	-84.15	-3.31	219.94	-199.4	-99.70	-3.93
62.	157.74	-177.4	-88.70	-3.49	221.02	-210.2	-105.10	-4.14
63.	158.64	-186.4	-93.20	-3.67	222.10	-221.0	-110.50	-4.35
64.	159.56	-195.6	-97.80	-3.85	223.19	-231.9	-115.95	-4.56
65.	160.49	-204.9	-102.45	-4.03	224.29	-242.9	-121.45	-4.78
66.	161.43	-214.3	-107.15	-4.22	225.35	-253.5	-126.75	-4.99
67.	162.35	-223.5	-111.75	-4.40	226.42	-264.2	-132.10	-5.20
68.	163.27	-232.7	-116.35	-4.58	227.49	-274.9	-137.45	-5.41
69.	164.15	-241.5	-120.75	-4.75	228.55	-285.5	-142.75	-5.62
70.	165.03	-250.3	-125.15	-4.93	229.58	-295.8	-147.90	-5.82
71.	165.90	-259.0	-129.50	-5.10	230.61	-306.1	-153.05	-6.03
72.	166.75	-267.5	-133.75	-5.27	231.64	-316.4	-158.20	-6.23
73.	167.59	-275.9	-137.95	-5.43	232.66	-326.6	-163.30	-6.43
74.	168.46	-284.6	-142.30	-5.60	233.70	-337.0	-168.50	-6.63
75.	169.30	-293.0	-146.50	-5.77	234.73	-347.3	-173.65	-6.84
76.	170.09	-300.9	-150.45	-5.93	235.75	-357.5	-178.75	-7.04
77.	170.97	-309.7	-154.85	-6.10	236.77	-367.7	-183.85	-7.24
78.	171.80	-318.0	-159.00	-6.26	237.77	-377.7	-188.85	-7.44
79.	172.65	-326.5	-163.25	-6.43	238.78	-387.8	-193.90	-7.63
80.	173.50	-335.0	-167.50	-6.59	239.79	-397.9	-198.95	-7.83

By graduating the free-lift scale bar to conform to the free lifts of balloons of various rates, this type of balance may be readily adapted to any ascensional rate, computed by any of the various formulas of the rate of ascent. Aside from the graduation of the free-lift scale bar, it is only necessary to make up the weight  $m$  to a mass of about one-half the sum of the maximum and minimum free lifts desired to be attained.

The best adjustment of the apparatus to give the greatest sensitivity and insure the greatest accuracy consists of the following: The hydrogen line support is set in the base of the balance on the back side, with the three-way stopcock toward the left-hand pan so that the reduced part is elevated from  $\frac{1}{4}$  to 1 inch above the connection on the nozzle assembly. The reduced arm of the nozzle assembly should be directed toward the fulcrum of the balance and about parallel with the three-way stopcock. When the  $\frac{1}{4}$ -inch rubber tubing is placed over the reducer and connected to the brass L it will then be supported mainly by the three-way stopcock, and any movement due to the oscillation of the balance will give a very slight torsion upon the 15-inch length of rubber tubing, the very principle upon which some of the most sensitive balances are constructed. The free-lift scale bar should be arranged so that the mid point of the bar is coincident with the fulcrum of the beam system.

In order to establish equilibrium throughout the beam system, it will be necessary to add a small amount of shot to the right-hand pan of the balance to counteract the weight of the nozzle assembly. A special recess, or basin, in the center of each pan is provided for this purpose. The finer adjustments of equilibrium can be made with the counterpoise weight mounted in the stem of the indicator over the fulcrum of the beam.

Using a filling apparatus to inflate to a definite rate of ascent is purely a mechanical operation. Having attached the hydrogen line to the short length of  $\frac{1}{4}$ -inch pipe on the hydrogen line support, figure 2, see that the three-way stopcock is open to admit the gas to pass to the nozzle. Then move the rider to the mid point of the free-lift scale bar, and see that the weight  $m$  is removed from the beam system. With the apparatus thus set, see that the beam system is in equilibrium and oscillates freely when unloaded; the counterpoise weight over the fulcrum will assist in this operation. This final adjustment should be tested for, and made if necessary, before each balloon is inflated.

After folding and rolling the balloon to expel the residual air, as explained in section 3, of *Instructions for Aerological Observers*, under *Inflation*, stretch the neck over the rim of the nozzle and lay the rolled portion of the balloon over the vent of the nozzle. The loose portion of the balloon should not be allowed to hang over the edge of the pan. Weigh the balloon by placing the small weights upon the right-hand pan of the balance, at

the same time noting that the 20-gram rider is set with the index over the mid point of the free-lift scale bar. Caution: To determine the accurate weight of the balloon, the weight  $m$  must be removed from the left-hand pan of the balance and the 20-gram rider must be set on the mid point of the scale bar. After determining the weight of the balloon in grams, move the rider to the corresponding graduations on the free-lift scale bar, remove the small weights from the right-hand pan, and attach the weight  $m$ . The setting is now complete for the definite inflation of that weight of balloon. For example, suppose that a balloon to be inflated to 200 m./min. was found to weigh 37 grams. The weights, by which the mass of the balloon was determined would be removed from the right-hand pan of the balance, the weight  $m$  (200 grams) would be placed in its designated position, and the rider would then be moved from its position at the mid point of the free-lift scale bar to the division 37. (See fig. 2.) The filling apparatus would then be set for the definite inflation of 200 m./min. for a balloon weighing 37 grams.

The application of the weight  $m$  will depress the left-hand pan of the balance and offer 2,000 gram-centimeters of force resistance to that side of the beam system. To support this weight it would require an inflation amounting to 200 grams free lift, but, by reference to Table 1, we need but 191.88 grams free lift to inflate a balloon weighing 37 grams to a rate of 200 millimeters. Thus, we have a difference of 81.2 gram-centimeters of force to overcome with the 20-gram rider. Now then by moving this rider to a position 40.6 millimeters (or 1.60 inches) to the right of mid-point of free-lift scale bar, the difference in moments of force would be accounted for.

When these settings are complete, the gas is turned on at the tank until equilibrium of the beam system is again established, then the gas is turned off. If too much gas is admitted to the balloon, the excess may be removed by opening the three-way stop cock, allowing it to escape into the air. The pressure of the gas in the balloon will be sufficient to drive out the excess, thus allowing a close adjustment of equilibrium of forces. The balloon is now sealed as instructed in Section 3 of *Instructions for Aerological Observers* under *Sealing*, and is in readiness for the observation.

A study of the sensitivity of the balance has shown it to be 1/10 gram or less. It is obvious that closer measurements of free lift can be made with the filling apparatus than is being made by the method of indefinite inflation. By the latter method, weights and free lifts are made only to the nearest whole gram, but by the definite method the graduations of the free-lift scale bar have been worked out to the hundredth part of a gram and graduated accordingly. Thus for a balloon of given weight one is enabled to inflate it to the nearest hundredth of a gram of free lift to attain a definite rate of ascent.

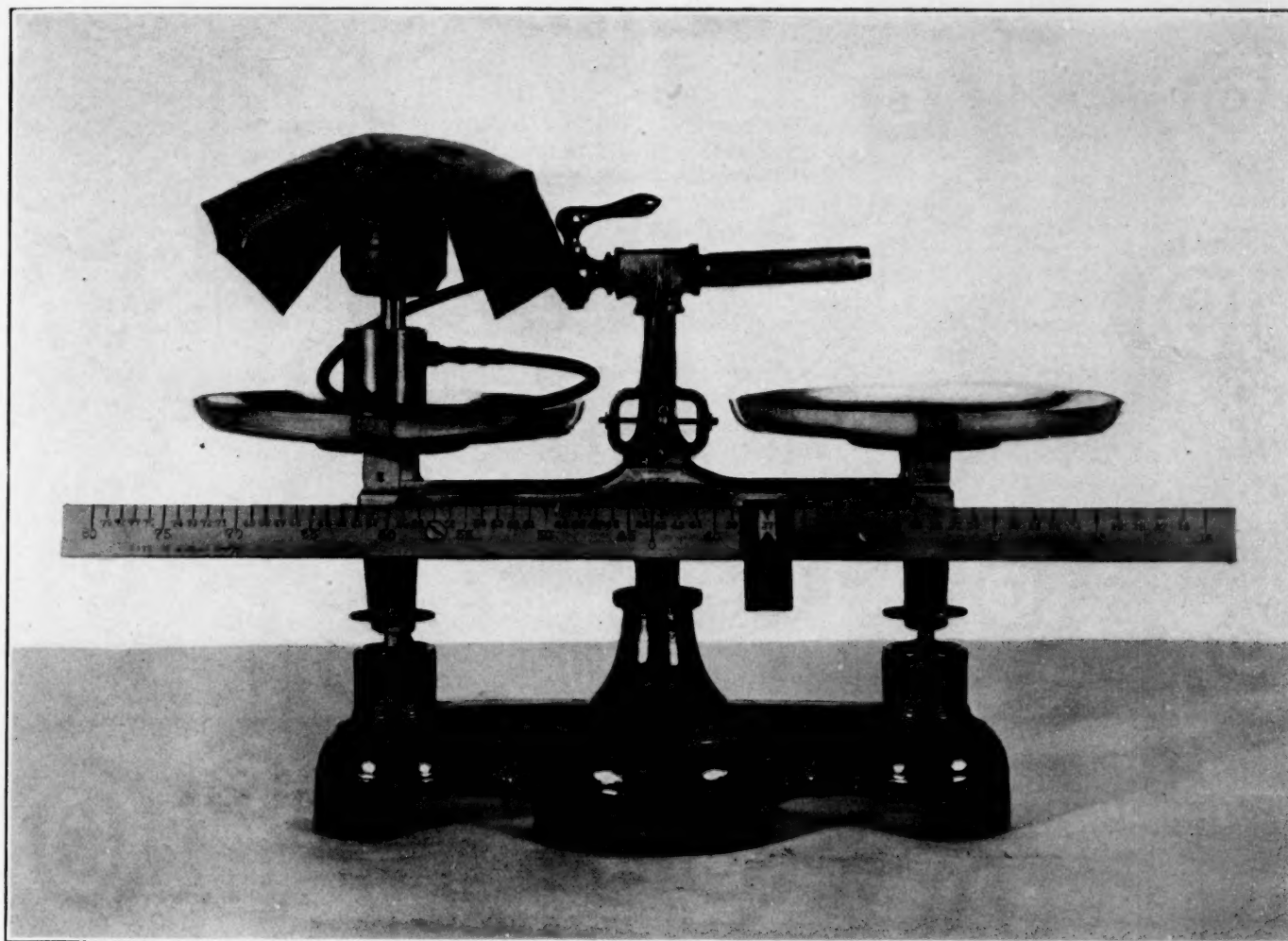
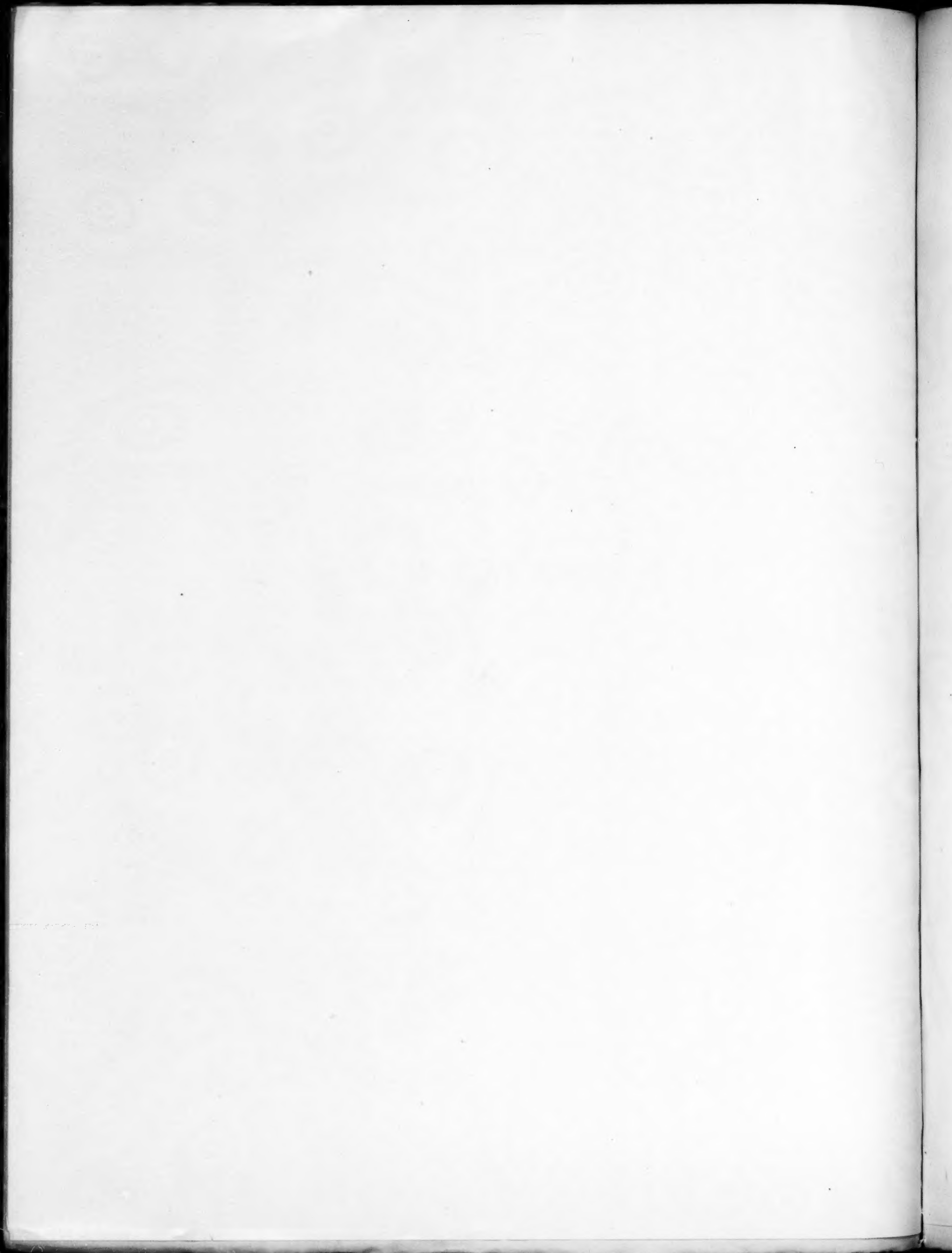


FIG. 2.—Filling apparatus with uninflated balloon attached.



## HISTORY OF THE THEORIES OF THE WINDS, FROM THE EARLIEST TIMES TO THE BEGINNING OF THE SEVENTEENTH CENTURY.

By EDGAR W. WOOLARD.

[Weather Bureau, Washington, D. C., Sept. 6, 1921.]

Meteorology as a science is young, but as a branch of knowledge it is very old, perhaps as old as mankind; the beginnings of meteorology are to be found with the origins of civilization. Meteorological phenomena must have been among the first natural occurrences to be noted by primitive man; and most prominent among these are the winds.

In remote times man living as a hunter or agriculturist, mostly in the open, was more influenced by, and more dependent on, the weather than we are ourselves at present; and he was therefore forced to watch atmospheric phenomena closely. He did so, of course, not in order to study the atmosphere and to discover its laws, but to derive immediate advantages for himself. He was

nxious to learn how to protect his house against the weather; how to foresee coming atmospheric conditions so that he might best plan his activities; and how to find out the most favorable climatic situations for various purposes. The experience of the more intelligent in these respects was handed down, and at the same time augmented from generation to generation, and very early formed an essential element in the knowledge of all races of mankind. For example, weather lore and weather superstitions existed among the Chaldeans and the Babylonians two or three thousand years before the Christian era; and the winds came in for a large share of attention.

The Babylonians had the wind rose of eight rhumbs, and used the names of the four cardinal points to denote the intermediate directions.<sup>1</sup> The Greeks and the Romans gave to each wind its own peculiar name, a practice still in use among Italian mariners in the Mediterranean.

All early science was essentially of a purely observational or descriptive nature. In meteorology, as in so many other fields, the Greeks, who played such a strong part in the development of all organized knowledge, were the first to attempt theories to account for the observed phenomena; however, early theoretical science was largely in the nature of arbitrary philosophical speculation; and the appeal was to authority rather than to experiment.

The Greeks were also the first to establish regular meteorological observations; observations of the winds prevail over all others, for they were of practical use for navigation and were easily made. The origin of the winds was always a favorite subject of speculation among philosophers. In the epoch of Homer (10th century B. C.?) the winds were still conceived of as absolute beings like gods. Anaximander of Ionia (5th century B. C.) was the first to give a scientific definition of the wind, and it is still valid: *The wind is a flowing of air.*

Since the time of the oldest philosophical school, that of Ionia (6th and 5th centuries B. C.), there have been few Greek philosophers who were not interested in some branch of meteorology. The subject then covered a wider field of research than at present, embracing, besides meteorology in the modern sense, also a good deal of physical geography and astronomy, especially shooting stars, meteors, and comets; the favorite meteorological subjects of speculation and research seem to have been

the origin of the winds, the theory of rain, and the rainbow.

Hippocrates (b. 460 B. C.), the "Father of Medicine," first enunciated the principles of public health in his treatise on *Airs, Waters, and Places*,<sup>2</sup> which included a consideration of the effects of winds. At an early period the Greeks used wind vanes, the "Tower of the Winds" at Athens,<sup>3</sup> constructed about the first century B. C., and still standing, affords interesting evidence of this. At that same time a contemporary Roman writer, Terentius Varro, tells us that in Roman villas wind vanes were constructed in such a manner as to show the direction of the vane on a wind rose fixed to the ceiling of the room. Yet no Greek or Roman word for wind vane has been handed down to us.

A good many cosmological speculations were put forward by the meteorologists, too, which often proved false, and, considered from a practical point of view, in all cases rather useless; whence in the period of Socrates (b. 470 ca. B. C.) meteorology itself came into disrepute; the Greeks had coined the word *μετεωρόλογος*, from *μετέωρα*, *supra-terrestrial*, and *λόγος*, *description or treatise*, to designate this branch of philosophy, and now a new word was formed, *μετεωρολόγος*, signifying a man babbling about sublime things. Nevertheless, meteorology made real progress; and a century later, about 350 B. C., the first treatise on meteorology, *τὰ μετεωρολογικά*, was written by the great Greek philosopher Aristotle (384-322 B. C.).

Aristotle's work contains a great deal of miscellaneous information of mixed value.<sup>4</sup> The section which deals with the winds forms one of the best parts of the book. Aristotle adopted the Greek view of the sphericity of the earth,<sup>5</sup> and regarded the globe as surrounded by successive envelopes of the other "elements," water, air, and fire. Although he laid down very excellent principles for scientific investigation, seemingly being the first to appreciate fully the importance of obtaining observational data before drawing conclusions, his own practical application of the method was defective, and his results not uniformly trustworthy.

<sup>1</sup> This work went through a number of editions and translations in later times. See, e. g., Hippocrates on *Airs, Waters, and Places*, the received Greek text of Littré, with Latin, French, and English translations by eminent scholars. London, Wyman & Sons, 1881. See also Hippocrates, *Opusculum repertorii prognosticon in mutationes aeris tam via astrologica quam meteorologica uti sapientes experientia compertientes soluerunt perquam utilissime ordinatum incipit sidere felici et primo problemum*. A. Petro de Albano in Latinum traductus. Venetiis, 1485. Herodotus (484-425 B. C.) wrote on the local winds of Egypt in his "Euterpe." The first edition of his works was in Latin, by Laurentius Valla, Venice, 1474; cf. Herodotus, tr. by Wm. Beloe, 4 vols., Philadelphia, 1814.

<sup>2</sup> See Hellmann, *op. cit.* The development of the meteorological ideas of the Greeks from the time of Homer is very fully treated in: Otto Gilbert, *Die meteorologischen theorien des griechischen altertums*. Leipzig, 1907.

<sup>3</sup> A complete bibliography of the editions and translations of Aristotle's *Meteorologica* is given by G. Hellmann, *Beiträge zur Geschichte der Meteorologie*, Band II, No. 6, pp. 1-45. *Veröff. d. Kon. Preuss. Met. Inst.*, No. 296, Berlin, 1917.

<sup>4</sup> The majority of the ideas of ancient races regarding the form and size of the earth, and the general scheme of cosmography into which they fitted the atmosphere, are valuable only as curiosities; here, too, the Greeks first held correct and scientific ideas. Astronomy, as originally introduced into Greece from Egypt by Thales (640-546 B. C.) of the Ionia school and by others, was a science of observation pure and simple. Later, Pythagoras (569?-497 B. C.) advanced the theory that the earth, in common with other heavenly bodies, is a sphere, and that it rests without support in the center of the universe; it is extremely doubtful whether he had any real evidence in support of his view, but the belief in the spherical form of the earth never disappeared from Greek thought, and in later times was an established part of the Greek systems (probably because of the affection which the Greeks always seem to have had for the circle and the sphere as being "perfect" bodies), being maintained by most of the later philosophers; the well-known proofs based on the change of altitude of the celestial pole with change of latitude, and the disappearance of the hulls of ships before that of the masts, were brought out by Aristotle and by Pliny (23-79 A. D.), respectively; Eratosthenes (275-194 B. C.) executed an actual measurement of the earth based on the first principle. Eratosthenes, Polybius, and Strabo were acquainted with the general distribution of temperature over the earth and its cause.

<sup>5</sup> See G. Hellmann: *The Dawn of Meteorology*. *Quar. Jour. Roy. Met. Soc.*, 34: 221-232, 1908.

<sup>6</sup> A device formerly attributed to Charles the Great (742-814 ca.) or to the monk Aleuin.

The atmosphere, according to Aristotle, is continually being traversed by two kinds of "exhalations" from the earth—an essentially watery vapor, and a peculiar, essentially dry, smoke-like exhalation from dry earth. Both are raised by the heat of the sun, and are always associated together. Unlike some ancient philosophers, Aristotle did not believe that air when in motion was wind, while the same air condensed was rain. He believed that rain originates from the vaporous exhalation and wind from the dry exhalation; he was influenced by observations showing that during dry years, when the dry and smoke-like exhalation was most abundant, winds were most frequent, while the vaporous exhalation was most abundant during wet years. Aristotle knew that winds were due to the action of solar heat, but beyond this his views on their production were untrustworthy.

Meteorology is essentially the physics of the air; but the physics and mathematics of this period were, of course, most rudimentary. Like most of other ancient philosophers, Aristotle's ideas about the composition of the atmosphere were very crude; air was usually considered to be an element; it is difficult to understand what he considered the dry exhalation to be, but it is probable that it was hot air mingled with humic and other effluvia rising from the hot earth. It is interesting to note that in the Aristotelian work *De Mundo* (probably not written by Aristotle), c. 4, 394, it is stated that wind is nothing else but a large quantity of compressed air in motion. Aristotle does not specifically state that winds are due to a disturbance of the equilibrium of the air, although he comes very close to it. (There was no knowledge of mechanics at that time; the first ideas about statics were put forward by Archimedes (287–212 B. C.) in his work on fluid pressure, and nothing more of any consequence in either statics or dynamics was accomplished until the beginning of the seventeenth century.)

Over most of the globe nothing seems so fickle and irregular—so subject to the whims of chance—as wind direction and speed. The conspicuous exceptions to this rule were early taken note of: The monsoons, or seasonal winds, of the Indian Ocean have been known since antiquity. Aristotle includes a description of them, and of the periodic winds of Greece, giving the characteristics of each. The great military expedition of Alexander the Great (356–323 B. C.) brought to the Greeks considerable knowledge of the monsoon winds.<sup>7</sup>

There is but little to record for the next 2,000 years. Aristotle's system of philosophy completely dominated all thought. His successors, such as Theophrastus (374?–287 B. C.),<sup>8</sup> Posidonius (c. 150–30 B. C.), et al., added little or nothing; but numerous commentaries and paraphrases were published. Among the Romans but little was done;<sup>9</sup> and during the Dark Ages meteorology was barely kept alive. The revival of learning at the end of the twelfth century saw only a firm and absolute adherence to the doctrines of Aristotle,<sup>11</sup> although some authors<sup>12</sup> did add opinions of their own, or of others.

<sup>7</sup> Before the time of Galileo (1564–1642) it was commonly supposed, on the authority of Aristotle, that every body had a "natural place," and that its normal state was one of rest in that place: E. g., a stone was supposed to sink in water because its natural place was at the bottom of the water.

<sup>8</sup> See T. E. Lones. *Aristotle's Researches in Natural Science*, London, 1912, Chaps. I–II. There have been two English translations of Aristotle's *Meteorology*—Pargiter, London, 1745; and Taylor, London, 1807—but copies are scarce. An excellent French translation, by J. Barthélemy Saint-Hilaire, with notes and the *De Mundo*, appeared at Paris, 1863. The winds occupy chaps. iv–vi, incl., of Book II. A translation was in preparation by E. W. Webster, who was killed in the World War.

<sup>9</sup> See Theophrastus of Eresus on *Winds and on Weather Signs*, by J. G. Wood, London, 1804. The Aristotelian theory is postulated; and concurrent and consequent phenomena of the winds, rather than the origin of the winds themselves, form the topic of discussion; also in the Loeb Classical Library: Theophrastus, *Enquiry into Plants and Minor Works*, vol. II, London, 1916. Tr. by Sir Arthur Hort.

<sup>10</sup> The extensive colonial possessions of the Romans occasioned the Romans to be the first to point out the difference between continental and maritime climate.

<sup>11</sup> Cf. Hellmann, *Dawn of Meteorology*, loc. cit.

<sup>12</sup> E. g. Albertus Magnus in his great meteorological works. See Theodor Schmitt *Die Meteorologie und Klimatologie des Albertus Magnus*, 1909.

The beginnings of experimental science are to be found just at that epoch when scholasticism had reached its highest point, namely, in the thirteenth century. It probably took its origin contemporaneously in France and in England, where the two friends Pierre de Maricourt (Petrus Peregrinus) and Roger Bacon (1214–1294) can be considered as the first great representatives of the new aims. Systematic meteorological observations began to make their appearance.

The knowledge of the Greeks had practically all been lost during the Dark Ages.<sup>13</sup> When, in the fifteenth century, the first beams of light broke in upon the darkness, and men began again to think about such things, here and there some asserted that the earth was not flat, but round; the voyage of Columbus, and the great explorations and geographical discoveries that quickly followed, convinced men that the earth is at least globular, and gave them some idea of its dimensions. These explorations were very fruitful in bringing to light many new facts of meteorology, and in introducing men to many new experiences in general.<sup>14</sup> A considerable amount of observational data began to be accumulated, and now and then summaries of it were undertaken. Peter Apianus, in his *Cosmographia*, 1524, gives a discussion of winds, with a chart of names, character, and distribution over the globe, in their application to navigation.

The first thorough exposition of the known distribution of winds over the Atlantic and the Pacific Oceans was brought out by the Spanish Jesuit José de Acosta in 1590;<sup>15</sup> the monsoons of the Indian Ocean, as mentioned above, had been known since antiquity;<sup>16</sup> the northeast trades were discovered by Christopher Columbus (1451?–1506) on his first voyage to America. Acosta, in agreement with the common belief at that time, attributed the regular easterly winds of the torrid zone (called *brisas* by the Spanish seamen) to a movement of the heavens about a stationary earth, in which the atmosphere partakes, but more slowly; the west and southwest winds of higher latitudes (*vendavales*) are modifications caused by ascending or descending currents.

The voyages of the great navigators of the sixteenth century sufficed to map out the Trades (so named by the English) quite completely, and furnished a fresh stimulus for meteorological observing in general. Descriptive literature dealing with the various occasional storms also began to appear.<sup>17</sup>

<sup>13</sup> Except in Arabia, where, e. g., a measurement of an arc of the meridian was carried out during this period.

<sup>14</sup> A bibliography of all textbooks of Meteorology published from 1500 to 1914 is given by G. Hellmann, *Beiträge zur Gesch. d. Met.*, Bd. II, Nr. 6, *Entwicklungsgeschichte des meteorologischen Lehrbuches*, pp. 67–133. *Veröff. d. Kon. Preuss. Met. Inst.*, Nr. 296, Berlin, 1917. All textbooks issued on the Continent till the end of the seventeenth century are exclusively based on Aristotle, but his influence in England was much less, although not so many treatises on meteorology were published in England before 1700. The following literature specially devoted to the winds is worthy of being listed: Ein *Hübischer schöner Kalender mit edlicher zugehörung . . . und von den vier Winden und ihrer Natur*. . . In fine: Getruckt zu Beutlingen von Michel Greyffler 1480.—Alkindus, Jacobus. *De pluvis, imbris, et ventis, ac aeris mutatione*. Venice, 1507. *De temporum mutationibus, sive de imbris nunquam antea excussis nunc vero per D. Jo. Hieronymum a Scaligis editis*. Paris, 1540.—Apianus, Peter. *Cosmographia*, Landshut, 1524, and many later editions.—Blondus (Blondus), M. A. *De ventis et navigatione*. Venice, 1546.—Magnus, Olaus. *De ventis*. In *Historia de gentibus septentrionalibus*. . . Rome, 1555.—Brevetano, Stefano. *Trattato dell'origine delli venti, nomi et proprietà, loro utile et necessario*. Venice, 1571.—Agrippa, Camillo. *Dialogo sopra la generazione de venti, baleni, tuoni, fulgori, fulmi, loghi, valli e montagne*. Rome, 1584.—Merkins, H. A., *De ventis incendi tempore orientibus*. Leipzig, 1587.—Damius, Friedrich. *De vento theses meteorologicae*. 1590.—Bonaventura, Franciscus. *De causa ventorum motus*. 1592. *Anemologiae pars prior, id est: De affectionibus, signis, causisque ventorum ex Aristotele, Theophrasto, ac Ptolemaeo tractatus*. 1593.—Mirovski, Andreas. *Theoria ventorum*. Wurtemberg, 1596.—Romanus, Adrian. *Ventorum secundum recentiores distinctorum usus*. Wurtemberg, 1596.

<sup>15</sup> José de Acosta (1539–1600). *Historia natural y moral de la Indias*. Sevilla, 1590; Salamanca, 1589 (in Latin). *The Naturale and Morale Historie of the East and West Indies*. London, 1604.

<sup>16</sup> In his work, *Muhit*, on the navigation of the Indian seas, published in 1554, the Turkish literary seaman Sidi Ali (Katibi Rumi) gives the times of commencement of the monsoon for 50 different places.

<sup>17</sup> The following are also of interest: Paluanus, Fabricius. *Tractatus duo, alter de ventis, alter de terrae motu*. 1601.—Drebbel, Cornelius. *Een port tractaat van de natuere der elementen, ende hoe sij veroorsecken der wint, regen, blikzen, donder, ende waeromme dienstich zijn*. Haarlem, 1604, 1621. Other editions in different languages, also.—Dissertations on the winds by Waldung, Welhamer, Werenberg, Scharlachius, Malapert, Wolfrum, Agerius, et al.—Schickard, Wilhelm. *Anemographia*. Tubingae, 1631.

Finally, the numerous events which were so greatly widening men's ideas and altering the prevalent conceptions of the world—the discovery of America, the circumnavigation of the globe and the other great exploring expeditions which followed, the overthrow of the Ptolemaic system of astronomy, et. al.—so helped to loosen the old foundations and to make plain the need for a new structure, that near the end of the sixteenth century a general reconstruction of all scientific ideas commenced. The Aristotelian writings and methods were bitterly assailed, and their influence commenced to wane. The new philosophy of Francis Bacon (1561–1626) was expounded in opposition to Aristotle's philosophy; the separate sciences became differentiated and classified, the scientific method emerged, and marked progress soon took place along both theoretical and experimental lines. Science in general, and meteorology in particular, entered upon a new era.<sup>18</sup>

#### UNUSUAL AURORA AT JUNEAU, ALASKA.

On the night of September 1, there occurred what is said by old residents to have been one of the most brilliant auroral displays that has been observed in Juneau in the last 20 years.

While the aurora began about 9 p. m. and continued until nearly midnight, it was most brilliant from 9:10 to 9:50 and from 11:35 to 11:55. The characteristic feature of the first period of brilliancy was a vivid band of white light, almost as bright as the full moon, that arched the sky from the western to the eastern horizon and about 5 degrees south of the zenith. This band varied in width, but averaged about 5 degrees. At frequent intervals there developed from it appendages of white light and weird shape, sometimes like "mare's tails" cirrus clouds and again like tongues of flame. Occasionally there would form on the northern side of the arch a wide appendage radiant with all the colors of the spectrum and that would shimmer in the most fascinating manner. These various appendages assumed form and disappeared gradually, and not with the rapidity that sometimes attends auroral formations. During the prevalence of the arch a faint glow of white light spanned the southern sky about azimuth 60 to 300, and with its crest at altitude about 40 degrees.

About 11:45, a long streamer of intense green shot from the southeast, extending past the zenith and curling and twisting like a whip-lash. Almost immediately further flashes appeared on the entire arc of horizon from south-

east through north to west. These grew in brilliancy and depth of coloring, and soon had become so strong that their light caused the neighboring landscape to be clearly visible, objects at the far side of town, nearly a mile away, being distinguishable.

The display continued to increase in intensity until 11:55, when it ceased with an abruptness that was startling. As though the "current had been shut off," every indication of the aurora vanished almost instantly and there was no further display during the night so far as known.

Earth currents attending the phenomenon affected the submarine cable connecting Juneau and Sitka to such an extent that from 9:20 to 10:25 p. m. and from 11:40 to midnight, when cable service closes for the night, it was utterly impossible to transmit or receive messages.—*M. B. Summers.*

#### HEAVY RAINS AND FLOODS IN LUZON, PHILIPPINES, AUGUST, 1921.

By JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I., Sept. 14, 1921.]

Although not a single typhoon traversed the Island of Luzon during the month of August, several distant typhoons that passed to the north were the cause of heavy rains and consequent floods over the western part of Luzon, particularly toward the middle of the month. Considerable damage was done to several Provinces by these floods. Manila was also flooded on the 16th, the water reaching the height of 1 meter (3 feet) in several portions of the city.

Following is the monthly total rainfall for a few of our stations as compared with the normal for August:

Station.	Amount.		Difference from the normal.	
	Millimeters.	Inches.	Millimeters.	Inches.
Manila.....	1,000.8	39.40	+398.5	+23.56
Baguio.....	1,848.8	72.79	+638.7	+25.15
Laos.....	1,244.1	49.97	+424.2	+16.70
Vigan.....	1,321.6	50.00	+802.5	+31.60
Iba.....	1,097.9	43.23	+97.4	+3.83

The maximum rainfall in 24 hours for the same stations was as follows:

Station.	Amount.		Date.
	Millimeters.	Inches.	
Manila.....	246.3	9.70	Aug. 15
Baguio.....	272.7	10.74	Aug. 14
Laos.....	278.7	10.97	Aug. 19
Vigan.....	243.9	9.60	Aug. 20
Iba.....	195.0	7.68	Aug. 15

<sup>18</sup> Cf. Walter Libby, *An Introduction to the History of Science*, New York, 1917. In the preparation of this paper use has been made of: H. H. Hildebrandsson and L. Teisserenc de Bort, *Les Bases de la Météorologie Dynamique*, Tome I, Paris, 1907; G. Hellmann's *Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus*; and the unpublished U. S. Signal Corps *Bibliography of Meteorology*, edited by O. L. Fassig, Part III, Winds Part IV, Storms.

The National Weather Bureau of the United States has received from the National Observatory of Cuba, under the direction of Dr. Carlos G. Carbonell, a collection of weather observations for the month of August, 1921. Dr. Carbonell has occupied this position since 1905, and has cooperated during this period with the United States Weather Bureau in the collection of

## NOTES, ABSTRACTS, AND REVIEWS.

## A CORRECTION.

A correspondent calls the attention of the Editor to certain inaccuracies in the article "R. L. S. As Meteorologist" which appeared in the MONTHLY WEATHER REVIEW, February, 1921, page 92. It is pointed out (1) that the residence of Stevenson in San Francisco was in a house on Powell Street near Bush and not in a house fronting on Portsmouth Square; (2) the article seems to imply that the monument in Portsmouth Square is the only one to Stevenson in the United States, whereas there is at least one other (at Calistoga, Calif.); (3) according to standard editions of Stevenson's works the quotation "Home is the wanderer, home from the sea" should read "Home is the sailor, home from sea."—EDITOR.

## Death of Dr. Julius Von Hann.

It is with profound regret that meteorologists in all parts of the world will receive the announcement of the death of Dr. Julius von Hann, former director of the Zentralanstalt für Meteorologie und Geodynamik, at Vienna. The notice just received from the Österreichische Gesellschaft für Meteorologie, states that Dr. von Hann died at his home in Vienna on October 1, after long illness. It will be recalled that after the war he, as well as other Austrian meteorologists, were reported to be in dire need, and, in this country, the American Meteorological Society promptly responded to the call for aid, sending assistance to the workers of the Zentralanstalt and to Dr. von Hann in particular. Although as yet, no information is available concerning the circumstances of his death, it is presumed that his advanced age (this being his 83d year), and the hardships that he has been obliged to undergo in the last several years were direct contributors. In the face of these facts, it is the more remarkable that he continued to write and publish scientific papers.

It is unnecessary to mention the many valuable papers containing results of careful and painstaking investigations, the important *Meteorologie und Klimatologie*, of which he was the author, or the *Meteorologische Zeitschrift*, of which he was an editor and founder, for they are known to all readers and students of meteorology; nor is it necessary to dwell upon the magnitude of the circle of influence that he commanded when it required 10 long lines of very small type in the notice of his death to list the abbreviated names of organizations, in all parts of the world, of which he was a member, the important positions he has held, and the honors he has received. Indeed, the statement—

Ein Leben ununterbrochener Geistesarbeit und reinster Forschung im Dienste der Wissenschaft ist abgeschlossen. Aber ungezählte Fäden führen von Hann's Werken in alle Länder der Erde und wirken in seinem Sinne fort.

will be received with universal approval.—C. L. M.

## Death of Director Carbonell of the National Observatory of Cuba.

Dr. Luis Garcia y Carbonell, director of the National Observatory of Cuba, died in Habana on October 11, 1921. Dr. Carbonell has occupied this position since 1905, and has cooperated during this period with the United States Weather Bureau in the collection of

meteorological information. He was just entering upon his eighty-second year, his death occurring the day following his eighty-first birthday.

At this writing the only notice regarding his successor is an unofficial news item which states that Dr. José G. Millas, has been appointed. Dr. Millas is well known in the United States, having done astronomical work at the Yerkes Observatory of the University of Chicago, and at the Naval Observatory at Washington.—C. L. M.

THE INFLUENCE OF THE ALPS ON PRESSURE OVER THE MEDITERRANEAN SEA.<sup>1</sup>

By HEINRICH FICKER.

When it is observed from charts of mean pressure distribution over Europe for two successive days that the center of an extensive depression moves from the Atlantic Ocean to a region east of Scandinavia, and when other conditions are favorable, there occurs typical development of a secondary depression south of the Alps, which formation is seen to replace a previously existing wedge-shaped area of high pressure.

This secondary minimum is explained by continuance of pressure fall south of the Alps until the passage of the axis of a "primary" pressure formation (depression) in the upper atmosphere, while north of the Alps pressure generally begins to rise with the earlier passage of the "squall line." It is assumed that the pressure wave of such a primary formation is not influenced by mountains and that its amplitude increases toward the earth in proportion to the increase in pressure. On the other hand, with sufficient height of the mountain the "secondary," thermal-advective wave—inrush of cold air, in reference to which the term squall line is used—has influence only on its windward side. Obviously the pressure contrast is greatest when the cold air reaches barely to the crest of the mountain; then on one side the pressure wave is purely primary, while on the other it is "composite" with marked intensity in the thermally produced, secondary element.

The existence of a secondary wave is proven when the rate of decrease in amplitude of pressure change with elevation is greater or less than the rate of decrease in observed pressure. With marked pressure fall south of the Alps reduction of pressure at stations on southern side, northern side, and summit to the elevation of the latter shows like fall for southern side and summit, less fall for the northern side. The secondary, thermal pressure wave, whose effect is to counteract the primary fall, has not reached the southern side of the Alps; the primary wave is "isolated" there.

This isolation of the primary wave is a relatively rare phenomenon, characteristic of a certain stage of development only; when the rising cold air overflows to the southern side in considerable volume the thermal wave begins to fill the secondary low pressure area, but this is not well effected until after the passage of the axis of the primary depression of the upper strata.

The center of this secondary minimum forming suddenly at the western end of the Alps, over the Gulf of Genoa, shifts eastward with lessening depth. It moves to the eastern end of the Alps and with the termination of the sheltering effect of the Alps disappears east of the

<sup>1</sup> Der Einfluss der Alpen auf Fallgebiete des Luftdruckes und die Entstehung von Depressionen über dem Mittelmeer. *Meteorologische Zeitschrift*, Dec., 1920, 37: 350-363.

Adriatic Sea. By far the greater number of Mediterranean depressions belong to this group; those approaching from the west as independent formations and those of the origin here discussed that change into long continuing depressions and move into Hungary are relatively few.

The wedge of high pressure, and not the pocket of low pressure encroaching on the Mediterranean Sea, is the disturbance feature of the first day. This, also, results from the isolating influence of the Alps. North of these mountains the depression is advancing with characteristic falling pressure and rising temperature at its front. At the south temperature conditions do not change; the mountains obstruct flow of air to the north-western depression and there is no thermal pressure wave—the primary wave is isolated. With horizontal supply of air from the south thus cut off the regions north of the Alps fill with air from aloft. This has potentially higher temperature and in its descent produces foehn effects and adds intensity to the primary pressure wave.—W. W. Reed.<sup>2</sup>

## NOTE.

Reference to weather maps for November 3, 7, 8, 10, 15, 16, 17, 26, 1917 shows that a deformation of isobars similar to that given in figure 4 of the paper (*Met. Zeit.* Dec. 1920, p. 35), is found south of the Appalachian Mountains (vicinity of Atlanta, Ga.), when an area of high pressure is approaching.

This may be due to an isolation of "primary wave of pressure," although it occurs with increasing pressure whereas the isolation occurs with diminishing pressure in the region of the Alps.

Mention is made of this since it may be thought interesting to note this in connection with the abstract above.—W. W. R.

## FORECASTING THE CROPS FROM THE WEATHER.

By R. A. HOOKER.

[Excerpts from the *Quarterly Journal of the Royal Meteorological Society*, April, 1921, 47: 75-99.]

There are two main lines of research which have attracted the attention of trained scientific men in the investigation of the conditions which induce good or bad crops. These two lines are firstly, the determination of a cycle of a definite number of years at the end of which similar meteorological and, as a consequence, agricultural, phenomena are reproduced; and secondly, the effects of different types of weather during or shortly before the growing season of the crops.

Concerning the first method I shall say but little, not because I wish to be regarded as skeptical of its practicability but because I am insufficiently versed in the matter. The second line of research consists in comparing deviations of the crops from the average with precedent deviations of various meteorological phenomena from the normal.

Early students were handicapped by lack of data concerning the crops and many of the crops were merely listed as "good" or "bad" thus making accurate summarization impossible.

The beginning of this branch of study started with the inquiry of Gilbert and Lawes, in 1880, of the relationships between the winter rainfall and the yield of wheat the subsequent autumn. They concluded, on the strength of 14 years data, that seasons of highest productiveness were characterized by higher than average temperatures during most of the winter and early spring, and a prevailing deficiency of rain in winter and spring.

An advance in scientific procedure is to be marked when actual statistics of crops begin to be available in sufficient quantity. Sir Rawson W. Rawson, in examining the relation between the rainfall and the sugar crops on the island of Barbados, found that for every inch of rainfall during the preceeding year, a yield of 800 hogsheads of sugar in the whole island [the area having been fairly constant for some years]. Thus he proposed to predict the crops by multiplying the preceeding years rainfall by 800.

England is far behind in "agricultural meteorology" although other countries have not advanced very far. The first author I mention outside England is S. M. Jacobs of the Indian Meteorological Society. In 1910, he published a paper in which he correlates the area of unirrigated "matured" autumn and spring crops with the rainfall of the preceding six months, obtaining various coefficients ranging up to +0.73 between the spring crop and rain in the preceding winter. This work does not take any one crop but all the crops combined.

Mr. Jacobs in his second paper marks an advance upon his earlier one, mainly in two directions; he now deals with individual crops and he utilizes Kincer's method of dealing with crops suspected of being grown under optimum conditions.

Among the results obtained in the second paper are the following: (1) The area sown with "well-irrigated" wheat in Jullundur is closely correlated, negatively, with the rainfall of August, September, and October, partial coefficients of -0.79, -0.86, and -0.74 respectively being found. (2) With unirrigated spring crops [taken together], the correlation coefficient is high and positive, September +0.74 thus a dry season leads to a reduction in the area of spring crops. (3) Turning to yield Jacobs correlates the deficiency below normal of "well-irrigated" wheat with the rainfall of various months. (4) With unirrigated wheat he gets regression equations which furnish a fair estimate only. He accordingly suspects that the conditions on such land are nearly optimum, and, following Kincer, weights the rainfall for each month with certain factors found empirically. Correlating this weighted rainfall with the area of unirrigated wheat, he obtains a coefficient of +0.91. This almost amounts to proof that, as far as regards precipitation, the climate of Jullundur is practically of optimum for wheat.

This work of correlating weather and crops is of paramount importance; to anticipate, with a reasonable degree of probability, a type of weather known to be injurious to crops will save many dollars.

The determination of the relationships between a crop and the weather ought to lead to the immediate application of the knowledge required to practical uses. But I have yet to find that the results obtained have hitherto been put to any such use, obvious and instant though the application may appear to be.

<sup>2</sup> Translation by Mr. W. W. Reed is on file in the Weather Bureau Library.

What of the future? Far more investigation is yet required into the behavior of different crops under different conditions of weather. One of the great organizations undertaking this work is the International Agricultural Institute founded by the King of Italy in 1905. This organization comprises representatives of practically every government on the face of the globe. It was founded primarily to give to farmers throughout the world information concerning supply and demand in various countries.

Some years ago, the institute appointed a permanent committee on agricultural Meteorology whose duties are: (1) Finding the importance of daily records of the weather in determining the statistics of the most favorable conditions. (2) Studying of the factors which contribute to the largest yield. (3) Studying the relation that exists between the totality of the crops and the aggregate of the various atmospheric phenomena. (4) Determination of the "good agricultural year" in relation to atmospheric conditions. (5) Studying the different elements necessary for a good harvest, e. g., amount of light, heat, humidity, rain, etc.

How little has been done toward the solution of these problems! Do we know the answer to a single one of these questions? Truly the task involved in these few apparently simple questions is a gigantic one, a task demanding the patient collaboration of a host of enthusiastic workers.

#### WORLD DEVIATION OF PRESSURE AND TEMPERATURE FROM NORMAL, 1910.

[Reprinted from *Nature* (London), Sept. 15, 1921, p. 97.]

Charts showing the deviation of the pressure and temperature from normal values for each month and for the year 1910, based on observations at land stations—generally two for each 10-degree square of latitude and longitude—have just been published by the Meteorological Office under the title "Reseau Mondial, 1910." The charts have been prepared to illustrate the tables which were issued in 1920, and a similar volume of charts for 1911 was published in 1916.

This world-wide meteorology will add much to our present knowledge of weather changes, which in many respects are exceedingly intricate; it is by such world-wide information that we may eventually hope to forecast for longer periods than is possible at present; and in time, perhaps, we may foresee the character of a coming season. Atmospheric pressure lines of equal deviation from normal are given for each five millibars, and for temperature the individual deviations are plotted for each station.

Among many other questions of interest such charts may render it possible to form some idea as to whether the pressure of the atmosphere is always practically uniform over the world as a whole. The charts in question would seem to suggest that it is, but a more detailed examination must be made to substantiate such a conclusion.

#### BIBLIOGRAPHY.

##### RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

##### Aichiken. Meteorological observatory.

Result of the meteorological observations made at Aichiken meteorological observatory for the 30 years 1891-1920. Aichiken. 1921. 60 p. 26 cm. [In English and Japanese.]

##### Birge, Edward A., & Juday, Chancey.

Further limnological observations on the Finger Lakes of New York. Washington. 1921. p. 211-252. 28 cm. (U. S. Bureau of fisheries. Bull., v. 37, 1919/20.)

##### Bell, P. L.

Colombia, a commercial and industrial handbook. Washington. 1921. 423 p. 23½ cm. (U. S. Bur. of foreign and domestic commerce. Special agents series, no. 206.) [With description of climate, in general and by districts.]

##### Davison, Charles.

Manual of seismology. Cambridge. 1921. 256 p. 22 cm. (Cambridge geological series.)

##### Eriksson, J. V.

Isläggning och islossning i Sveriges insjöar. Uppsala. 1920. 95 p. 32 cm. (Statens met.-hydrogr. anstalt. Meddelanden. Bd. 1, no. 2.) [With résumé in French.]

##### Gruner, P.

Beiträge zur Kenntnis der Dämmerungs-Erscheinungen und des Alpenglühens. I. Historisch-chronologische Übersicht der schweizerischen Beobachtungen und Veröffentlichungen über Dämmerungsfarben und Alpenglühen. Zurich. 1921. 245 p. 29 cm. (Schweiz. naturforsch. Gesellsch. Denkschr. Bd. 57, 1921.)

##### Helland-Hansen, Björn, & Nansen, Fridtjof.

Klimavekslinger og deres årsaker. (Reprint from "Naturen," 1920. p. 12-28; 101-116; 347-361.)

##### Hellmann, Gustav.

Die Meteorologie in den deutschen Flugschriften und Flugblättern des XVI. Jahrhunderts. Berlin. 1921. 96 p. 27½ cm. (Preuss. Akad. der Wissensch. Abh. 1921. Phys.-math. Klasse, nr. 1.)

Neue Untersuchungen über die Regenverhältnisse von Deutschland. 2. Mitteilung: Die Schneeverhältnisse. Berlin. 1921. p. 246-257. 25½ cm. (Preuss. Akad. der Wissensch. Sitzungsberichte. 11, 1921.)

##### Hesselberg, Th.

Weather-warnings for airmen in Norway. (From Geografiska annaler, Stockholm. 1920, H. 2. p. 119-130.)

##### Kleinert, Heinrich.

Beitrag zur der Theorie des Purpurlichts. Bern. 1921. p. 71-77. 23 cm. (Inaug. Diss. [extract], Bern.) (Philosoph. Fakultät II der Univ. Bern. Jahrb., Bd. 1, 1921.)

##### Kuhlbrodt, Erich.

Klimatologie und Meteorologie von Mazedonien. Ein Beitrag zur Klimakunde der Balkanhalbinsel. (Unter Berücksichtigung der Windverhältnisse in der Höhe.) Hamburg. 1920. 61 p. 29 cm. (Aus dem Archiv der Deutschen Seewarte, 38 Jahrg. 1920.)

##### Lalesque, F.

Arcahon, ville de santé. Paris. 1919. 798 p. 24 cm.

##### Lévine, Joseph.

Atlas météorologique de Paris. Paris. 1921. 83 p. maps. 32 cm.

##### Prussia. Preussisches meteorologisches Institut.

Klima-Atlas von Deutschland. Berlin. 1921. 40 p. 63 plates. 32 x 36 cm.

##### Remy, Lieut.

Précis de météorologie pratique à l'usage des aviateurs. 2d ed. Paris. 1919. 95 p. 22 cm.

##### Schurz, W. L.

Bolivia, a commercial and industrial handbook. Washington. 1921. 260 p. 23½ cm. (U. S. Bur. of foreign and domestic commerce. Special agents series, no. 208.) ["Climate," p. 17-22.]

**Smosarski, W.**

Cienie obłoków na tle nieba i ich związek ze światłem dziennym. Ombres de nuages sur le fond du ciel et leur relation avec la lumière du jour. Warsaw. 1916. p. 777-800. 26½ cm. (Soc. des sciences de Varsovie. Comptes rendus. 1916. 9 an. Fasc. 7.)

Kilka obserwacji zanikaniz obłoków klebiastych. Quelques observations sur la disparition des nuages. Poznań. 1921. 12 p. 22½ cm.

Niezwykła szadź i osobliwy szron. Ausserordentliche Raueisbildung und sonderbarer Reif. Warsaw. 1918. p. 432-442. 25½ cm. (Soc. des sciences de Varsovie. Comptes rendus. 1918. 11 an. Fasc. 4.)

O pewnym typie obłoków. Sur un type de nuages. Warsaw. 1915. p. 366-377. 25½ cm. (Soc. des sciences de Varsovie. Comptes rendus. 1915. 8 an. Fasc. 6.)

**Spitaler, Rudolf.**

Das Klima des Eiszeitalters. Prag. 1921. 138 p. 31 cm.

**Sutton, J. R.**

Sun spots and earth temperatures. (Reprint from Roy. soc. of S. Africa. Trans., Capetown. v. 10, pt. 1, 1921. p. 57-59.)

Rainfall and the pressure gradient. (Reprint from Roy. soc. of S. Africa. Trans., Capetown. v. 10, pt. 1, 1921. p. 61-64.)

**U. S. Bureau of standards.**

Testing of thermometers. 3d ed. Washington. 1921. 18 p. 25½ cm. (Circ. no. 8.)

**U. S. Weather bureau.**

Instructions for the installation and maintenance of Marvin water-stage registers with specifications, by Roy N. Covert. Washington. 1921. 23 p. 23 cm. (Instrument division. Circ. J.)

**RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.**

C. F. TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

*Aérophile. Paris. 29 année. 1-15 août, 1921.*

Roux, G. La météorologie aéronautique. L'Office national météorologique. Les observations météorologiques intéressant la navigation aérienne: organisation, transmission. Leur utilisation par les navigateurs aériens. p. 253-254.

*American society of civil engineers. Proceedings. N. Y. v. 47. Sept., 1921.*

Grunsky, C. E. Rainfall and run-off studies. p. 203-242.

Munn, James, & Savage, J. L. Flood of June, 1921, in the Arkansas river, at Pueblo, Colorado. p. 167-201.

*Aviation and aircraft journal. N. Y. v. 11. Oct. 17, 1921.*

Brandtl, L. Soaring flight. p. 459.

*Bulletin astronomique. Paris. T. 1, fasc. 4, 1921.*

Hamy, Maurice. Sur un cas particulier de diffraction des images des astres circulaires. p. 197-212.

*Great Britain. Meteorological office. Monthly meteorological charts, East Indian seas. Oct., 1921.*

Durst, C. S. Mechanical means of extracting data from meteorological logs and of working up averages.

*Great Britain. Meteorological office. Monthly meteorological charts, East Indian seas. Nov., 1921.*

Keeton, H. Swell.

*Heating and ventilating magazine. New York. v. 18. Oct., 1921.*

Greenburg, Leonard. Extent of the experimental error involved in the factoring of katathermometer. p. 37-40.

Humidifying devices for the home. p. 56.

*Journal of geography. Chicago. v. 20. Oct., 1921.*

Visher, Stephen S. Preparation for teaching climate. p. 252-264.

74777-21-3

*Kristiania. Geofysiske kommission. Geofysiske publikationer. Christiania. v. 2, no. 1. 1921.*

Köhler, Hilding. Zur Kondensation des Wasserdampfes in der Atmosphäre. pt. 1. 15 p.

*Meteorological magazine. London. v. 56. Sept., 1921.*

Brooks, C. E. P. Could the drought of 1921 have been forecasted? p. 211-215.

Cave, C. J. P., & others. Units for meteorological work. p. 221-223.

Chree, C. Diurnal variation in atmospheric pollution and in electrical potential gradient. p. 205-208.

Dines, L. H. G. Humidity observations as an aid to estimating cloud-height. p. 226-228.

Gold, E. Meeting of the International commission for the scientific investigation of the upper air, at Bergen. p. 215-217. [See Aug. Review, p. 461.]

J., H. Results of the ball lightning inquiry. p. 208-211.

Priestley, Charles F. Visibility on the Firth of Clyde. p. 224.

*Nature. London. v. 108. 1921.*

Fisher, Willard J. Duration of sunrise and sunset. p. 211-212. (Oct. 13.)

Rayleigh. Occurrence of the aurora line in the spectrum of the night sky. p. 208. (Oct. 13.)

*Physical review. Lancaster, Pa. v. 18. Aug., 1921.*

Dorsey, Herbert Grove. Peculiar ice formations. p. 162-164.

King, Louis V. On the measurement of the acoustic output and efficiency of fog-alarm apparatus. p. 120-121.

Mauchly, S. J. Note on the diurnal variation of the atmospheric electric potential gradient. p. 161-162.

*Popular astronomy. Northfield, Minn. v. 29. Oct., 1921.*

Wylie, Charles Clayton. Effect of the barometric gradient on meridian observations. p. 479-481.

*Royal society of London. Philosophical transactions. London. ser. A. v. 222. 1921.*

Walker, George W. Problem of finite focal depth revealed by seismometers. p. 45-56.

*Royal society of South Africa. Transactions. Capetown. v. 10. pt. 1, 1921.*

Sutton, J. R. Rainfall and the pressure gradient. p. 61-64.

Sutton, J. R. Sunspots and earth temperatures. p. 57-59.

*Science. New York. v. 54. 1921.*

Meisinger, C. LeRoy. Determining the true mean temperature. p. 276-277. (Sept. 23.) [Abstr. from Mo. WEATHER REV., Apr., 1921. pp. 226-229.]

Curtis, Heber D. On sounds accompanying auroral displays. p. 301-302. (Sept. 30.)

Brooks, Charles F. Grand aurora of September 1-2, 1921 (at Silver Lake, N. H., lat. 43.9° N.), p. 329-330. (Oct. 7.)

*Scientific American. New York. v. 125. Oct. 1, 1921.*

Winters, S. R. Getting a line on the higher atmospheres. p. 233-243. [Description of Fergusson's meteorograph.]

*Società meteorologica italiana. Bollettino bimensuale. Torino. v. 40. Lug.-Sett., 1921.*

Bettoni, Pio. Lo studio delle nubi. p. 42-46.

Crestani, Giuseppe. Le nubi a brandelli. p. 39-42. [Proposes the common name *fracti* for fracto-cumulus, fracto-nimbus and fracto-stratus. This suggestion is slightly modified in an appendix.]

Di Veste, A. La pioggia considerata su piani verticali orientali (pioggia obliqua). p. 58-59. [Abstract.]

Gabba, Giovanni Celoria. p. 37-39. [Obituary.]

Marini, Luigi. Note climatiche per le principali città costiere dell'Adriatico. Venezia. p. 46-58.

*Wetter. Berlin. 38. Jahrg. Juli/Aug., 1921.*

Freybe, O. Die Wettervorhersagen von Hinselmann. p. 115-116.

Huber, U. Eine Fata morgana am Monte Rosa. p. 102-104.

Knoch, K. Die Beziehungen zwischen dem Massenschwärm der Kriebelnücken und der Lufttemperatur. p. 113-114.

Molly, Schnelle Wolkenbildung durch Rauch. p. 119-120.

Naegler, Wilhelm. Normalkalender für Temperatur und Niederschlag in Deutschland. p. 106-109.

Peppler, W. Einige neuere Arbeiten über die Verwendung der Zirren für die Wettervoraussage. p. 116-119.

Peppler, W. Ueber "brecherartige" Wolkenformen. p. 97-102.

Wussow, G. Die Schneefälle und Gewitterregen im Mai 1921 in Nord-Deutschland. p. 109-112.

## SOLAR OBSERVATIONS.

## SOLAR AND SKY RADIATION MEASUREMENTS DURING SEPTEMBER, 1921.

By HERBERT H. KIMBALL, Meteorologist.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, 48: 225.

From Table 1 it is seen that direct solar radiation intensities were generally slightly above normal September values at all the stations except at Lincoln, Nebr., during afternoon hours. Table 2 shows that the total solar and sky radiation received on a horizontal surface was generally above the September normal at Madison except during the second week, and below the normal at Washington.

Skylight polarization measurements made on six days at Washington give a mean of 54 per cent and a maximum of 69 per cent on the 19th. At Madison, measurements obtained on 11 days give a mean of 69 per cent and a maximum of 76 per cent on the 18th. These are average values for September at Washington, but slightly above the average at Madison.

TABLE 1.—Solar radiation intensities during September, 1921.

(Gram-calories per minute per square centimeter of normal surface.)

## Washington, D. C.

		Sun's zenith distance.											
		8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon	
Date.	75th meridian time.	Air mass.										Local mean solar time.	
		A. M.					P. M.						
		a.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0		e.
Sept. 1.....	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.	
2.....	17.37				0.67							17.96	
3.....	19.86					1.15						16.79	
4.....	12.68					1.36						11.38	
5.....	9.14			0.74	0.84	1.09						10.97	
6.....	8.81	0.87	0.97	1.07	1.23	1.44	1.15	0.99				8.81	
14.....	13.13				1.24	1.46	1.17	0.98	0.86	0.71		9.47	
19.....	11.38	0.63	0.73	0.85	1.09	1.27						11.38	
23.....	10.21			0.91	1.05							16.79	
Means.....		(0.75)	0.81	0.92	1.06	1.34	(1.16)	(0.98)	(0.86)	(0.71)			
Departures.....		+0.10	+0.07	+0.03	-0.01	+0.02	+0.11	+0.11	+0.13	+0.04			

## Madison, Wis.

Sept. 1.....	17.96		0.67	0.84	1.05	1.32					17.37
2.....	16.20				0.96						17.37
5.....	11.38		0.98	1.12	1.27	1.49					9.47
6.....	13.13				1.13	1.37	1.22	1.01			16.20
7.....	15.11				1.10	1.32					10.97
12.....	7.57		0.90	1.04	1.19	1.37					7.87
13.....	11.38				1.02						9.83
18.....	8.48		1.04	1.16	1.31	1.48					9.83
21.....	8.48			1.12	1.26	1.41	1.23	1.06			9.14
22.....	8.18	0.78	0.86	0.98	1.17	1.09					10.59
23.....	8.81		0.87			1.46					9.83
26.....	7.04	0.92	1.00	1.10	1.29	1.46	1.25	1.02			7.29
28.....	6.76		1.02	1.14	1.29	1.44	1.26	1.11			6.50
29.....	16.20		0.71								11.81
30.....	6.27					1.42	1.27	1.14			6.50
Means.....	(0.55)	0.89	1.06	1.17	1.41	1.22	1.07				
Departures.....		-0.04	-0.01	+0.04	+0.00	+0.03	+0.06	+0.05			

TABLE 1.—Solar radiation intensities during September, 1921—Contd.

## Lincoln, Nebr.

Sun's zenith distance.													
Date.	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.		
	75th meridian time.	Air mass.										Local mean solar time.	
		A. M.					P. M.						
		e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0		e.
Sept. 3.....	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.		
5.....	9.14		0.95	1.07	1.21	1.36	1.06	0.86	0.69	0.57	17.96		
6.....	10.59			1.03	1.23	1.42	1.21				10.59		
8.....	13.61			1.01	1.11	1.26	1.14	0.89	0.67	0.60	17.37		
9.....	16.79			0.94	1.09	1.27					15.65		
14.....	15.11			0.95			1.10	0.79	0.63	0.52	19.89		
17.....	13.61								0.88	0.77	13.13		
20.....	14.10		0.86	1.05	1.24	1.39	1.06				17.96		
21.....	7.57		1.03	1.14	1.28	1.49		1.12	0.83	0.75	10.97		
22.....	9.83		0.94	1.16	1.29	1.50	1.26	1.10	0.96	0.85	8.81		
23.....	13.61		0.88	1.04	1.20	1.38		0.94	0.86	0.79	17.96		
26.....	9.14		0.86	1.00	1.15	1.33					16.20		
28.....	7.87			1.08	1.25	1.43	1.09	0.84	0.69	0.59	14.10		
30.....	4.75		0.90	1.17	1.32	1.48		1.00	0.86	0.74	8.18		
Means.....		0.92	1.05	1.22	1.39	1.13	0.94	0.79	0.69				
Departures.....		+0.07	+0.04	+0.03	+0.00	-0.02	-0.03	-0.04	-0.04				

## Santa Fe, N. Mex.

Sept. 8.....	5.36					1.51	1.36	1.20	1.13	1.03	3.63
9.....	4.17	1.04	1.15	1.27	1.41	1.56	1.46	1.30	1.18		3.99
10.....	4.17	1.10	1.19	1.31	1.41	1.52					4.37
12.....	7.29		1.06	1.23				1.17	1.04	0.93	8.81
13.....	9.14					1.49	1.38	1.21	1.12	1.04	6.76
14.....	6.02	0.99	1.11								6.50
20.....	3.81		1.17	1.25							3.81
21.....	3.99			1.26	1.43	1.62	1.46	1.30	1.18	1.09	3.30
Means.....	1.04	1.14	1.26	1.42	1.54	1.41	1.24	1.13	1.02		
Departures.....		+0.07	+0.07	+0.09	+0.10	+0.01	+0.01	+0.01	+0.00	+0.01	

\* Extrapolated.

TABLE 2.—Solar and sky radiation received on a horizontal surface.

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Wash- ington.	Madison.	Lincoln.	Wash- ington.	Madison.	Lincoln.	Wash- ington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Sept. 3....	379	385		-19	+5		+2,000	-3,821	
10....	392	298		+10	-41		+2,068	-4,109	
17....	367	385		+1	+56		+2,073	-3,716	
24....	296	370		-54	+49		+1,695	-3,374	

## MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE, AUGUST, 1921.

By C. G. ABBOT, Assistant Secretary.

(Smithsonian Institution, Washington.)

NOTE.—The above report not having been received from South America in time to include here will be published in the October issue of the REVIEW.—EDITOR.

## WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

## NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was somewhat below the normal at land stations on the south coast of Newfoundland; it was slightly above in the Gulf of Mexico and nearly normal on the Atlantic coast of the United States.

The number of days in which fog was observed was apparently less than usual, as comparatively few fog reports were received.

The number of days with winds of gale force was considerably above the normal, especially in southern waters and over the western section of the steamer lanes, due to the unusually severe and protracted hurricanes of tropical origin.

From the 2d to the 4th there were moderate disturbances over different portions of the steamer lanes as shown by the following storm logs.

Belgium S. S. *Sunoco*:

Gale began on the 2d, wind SSW. Lowest barometer 29.50 inches at 7 a. m. on the 2d, wind S. 9; position, latitude 46° 28' N., longitude 32° 22' W. End of gale 9 a. m. on the 2d, wind WSW. Highest force of wind 10, S.; shifts S.-WSW.-W.-NW.

British S. S. *Rexmore*:

Gale began on the 3d, SSE. Lowest barometer 29.56 inches at 8 a. m. on the 3d, S., 8; position, latitude 52° 04' N., longitude 20° 29' W. End of gale on the 3d, W. Highest force of wind 8, S.; shifts SSE.-E.-SSW.

American S. S. *Asquam*:

Gale began on the 4th, WSW. Lowest barometer 29.59 inches at 2 a. m. on the 4th, N.; position, latitude 47° N., longitude 38° W. End of gale on the 4th. Highest force of wind 9, WSW.; shifts WSW.-W.

On the 5th, 6th, and 7th, conditions were comparatively quiet, except that on the 6th and 7th there was a disturbance of limited extent off the coast of Mexico, near Tampico. The American S. S. *Danville* reports:

At Tampico, Mexico, 7 p. m. on the 6th, SE. wind, hurricane force, barometer 29.41 inches.

Storm log from American S. S. *A. C. Bedford*:

Gale began on the 7th, SE. Lowest barometer 29.62 inches at 4 a. m. on the 7th, S. 9; position, latitude 22° 50' N., longitude 97° 03' W. End of gale on the 7th, S. Highest force 9; shifts SE.-S.

There will be found elsewhere a description of the tropical hurricanes, together with chart showing tracks from the 8th to the 15th.

On the morning of the 8th the Dutch S. S. *Noorderdijk*, although some distance from the center of the LOW, experienced strong southwesterly winds, as shown by following report:

From 4 to 8 a. m. on the 8th, fresh ESE. gale, shifting and decreasing to strong SW. breeze. High SE. swell, shifting and decreasing to light SW. Heavy rain.

On the 8th there was also a well defined LOW near latitude 50 N., longitude 28 W. Storm log follows:

American S. S. *Potomac*:

Gale began on the 8th, SW., 6. Lowest barometer 29.54 inches, 10 a. m. on the 8th, SW., 10; position, latitude 47° 07' N., longitude 29° 04' W. End of gale on the 8th, NW. Highest force of wind 10, SW.; shifts WSW.-W.-WNW.

This low moved rapidly eastward and on the 9th the center was about 400 miles west of the coast of Scotland. Storm log follows:

Danish S. S. *Hellig Olav*:

Gale began on the 9th, SSE. Lowest barometer 29.10 inches at noon on the 9th, SE.; position, latitude 57° 45' N., longitude 13° 35' W. End of gale on the 10th, WSW. Highest force of wind 8; shifts SSW.-W.-WSW.

On the 9th there was also a limited disturbance north of Bermuda as shown by storm log from the American S. S. *Remus*.

Gale began on the 9th, S. Lowest barometer 29.62 inches at 3 p. m. on the 9th, S. 10; position, latitude 38° 12' N., longitude 63° 05' W. End of gale on the 9th, S. Highest force of wind, 10, S.; steady from south.

The American S. S. *Claire*, on her voyage from Humacao on the south coast of Porto Rico to San Juan, experienced moderate easterly to southeasterly gale with frequent rain squalls on the night of the 9th and morning of the 10th.

The depression that was north of Bermuda on the 9th moved slowly toward the northeast, and on the 10th was central near latitude 42° N., longitude 55° W. While only moderate winds were reported at Greenwich noon on the 10th, heavy weather was encountered later in the day as shown by following storm logs:

American S. S. *Bethelbridge*:

Gale began on the 10th, SW. Lowest barometer 29.78 inches at 10 a. m. on the 10th, S. 8; position, latitude 39° 40' N., longitude 55° 04' W. End on the 10th, NW. Highest force of wind, 8, SSW.; shifts SSW.-S.

Danish S. S. *United States*:

Gale began on the 10th, ENE. Lowest barometer 29.32 inches at 5 p. m. on the 10th, ENE, 10; position, latitude 42° 22' N., longitude 52° 07' W. End of gale, 7 p. m. on the 10th, NE. Highest force of wind 10, ENE.; shifts ENE-NE.

Charts IX to XVI show the conditions from September 11 to 18, inclusive. So many reports and storm logs were received from vessels that encountered heavy weather during this period, it was found impossible to give them all here on account of limited space. A number of the more characteristic follow.

Dutch S. S. *Amsteldijk*:

Gale began on the 12th, SSE. Lowest barometer 29.77 inches at 4 a. m. on the 14th, S. 8; position, latitude 25° 42' N., longitude 66° 30' W. End of gale on the 14th, WSW. Highest force of wind 8, S.; shifts SSE.-SSW.-SW.

American S. S. *Glendoyle*:

At 4 p. m. on the 10th, wind NW., 3, barometer 29.68 inches; midnight, NW., 5, 29.58 inches; 4 a. m. on the 11th, NNW., 11, 29.30 inches; 8 a. m. WSW., 10, 29.49 inches. Noon S, 5, 29.65 inches. Ship's position stationary at latitude 18° 27' N., longitude 69° 18' W.

American S. S. *Cook*:

Gale began on the 10th, SE. At 4 p. m. on the 10th wind SE., 8, barometer 29.87 inches; position, latitude 28° 51' N. longitude 63° 28' W.; 8 p. m. SE., 8, 29.84 inches; midnight, SE., 8, 29.73 inches; 4 a. m. on the 11th, SE., 8, 29.65 inches (lowest barometer). End of gale at 8 a. m. on the 11th. Highest force of wind 9, SE.; shifts SE.-N.

British S. S. *Finchley*:

From 8 a. m. on the 11th wind increasing and backing from SE. to E. High SE. swell began at 9 a. m., being very pronounced from 1 to 3 p. m.; 4 to 5 p. m., sea had breaking tops, wind E., S.; barometer 29.50 inches at 5 p. m. Wind and sea moderate during the night. At 7 p. m. on the 12th began to rain, wind SE., 5; 10 p. m. wind force 9, Midnight force 10. 12:15 to 12:45 a. m. on the 13th calm with heavy rain. At 12:45 wind resumed with increased force from SE. From 6 to 8 a. m. wind E., force 11. Ship hove to from 9 a. m. to 12:30 p. m., wind NE. At 12:30 wind shifted from NE. to NNW., blowing with increased force, moderating at 6 p. m. when it backed to SW. Lowest barometer 28.56 inches at 11 a. m. on the 13th. Estimated position at 8 p. m. on the 12th, latitude 27° 50' N., longitude 69° 50' W.

American S. S. *Holyoke Bridge*:

Gale began on the 12th, E. Lowest barometer 29.61 inches at 2 p. m. on the 12th, NE.; position, latitude 32° 45' N., longitude 63° 20' W. End at 8 p. m. on the 12th, NW. Highest force of wind 11. Shifts E.-ENE.-NE.-N.

**American S. S. West Durfee:**

At 2:30 p. m. on the 12th barometer began falling, wind increasing steadily to force 8 at midnight when barometer read 29.71 inches. Wind then began to shift slowly, barometer rising. At noon on the 15th, wind SW., 4. Position at 2:30 p. m. on the 12th, latitude 32° 30' N., longitude 57° 34' W.

**American S. S. Oregonian:**

Gale began on the 12th, SSW. Lowest barometer 29.42 inches at 1 p. m. on the 12th, SW., 7; position, latitude 49° 50' N., longitude 23° W. End of gale on the 12th, NW. Highest force of wind 10; shifts SW.-NW.

**British S. S. Naperian:**

Gale began on the 12th, SW. Lowest barometer 29.75 inches at 2 a. m. on the 13th, NW., 7, in the English Channel. End of gale on the 14th, NNE. Highest force of wind 9; shifts SW.-NW.-WSW.

**American S. S. Capillo:**

7:22 p. m. (Greenwich time), September 11th; position, latitude 30° 50' N., longitude 63° 54' W.; wind ESE., 9; barometer 29.58 inches. 9:26 p. m., ENE., 12, barometer 29.10 inches (lowest reading); 12:32 a. m. on the 12th, NW., 9, 29.80 inches; 3:39 a. m., on the 13th, wind variable 4, barometer 29.96 inches; position, latitude 29° 23' N., longitude 70° 08' W. 9:52 a. m., NNE., 12, 29.50 inches; 2 p. m. NE., 10, 29.72 inches. 4:04 p. m., NNW., 6, 29.86 inches; position latitude 28° 25' N., longitude 72° 23' W.

**British S. S. Caledonian:**

Gale began on the 12th, ENE. Lowest barometer 29.15 inches on the 14th; position, latitude 55° 54' N., longitude 11° 50' W. End of gale on the 14th, NW. Highest force of wind 8; shifts SW.-WSW.-W.

**American S. S. Holyoke Bridge:**

Gale began on the 14th, ESE. Lowest barometer 29.19 inches at noon on the 15th, SSW., at Bermuda. End 7 p. m., on the 15th, NW. Highest force of wind 12; shifts S.-SSW.-SW.-WSW.-W.

**British S. S. War Nizam:**

Gale began on the 14th, NNE. Lowest barometer 28.76 inches at noon on the 14th, NE., 11; position, latitude 43° 40' N., longitude 48° 30' W. End on the 14th, NW. Highest force of wind 11; shifts ENE.N.

**Italian S. S. Giuseppe Verdi:**

Gale began on the 14th, SW. Lowest barometer 29.14 inches at 9 p. m. on the 14th, SW., 10; position, latitude 42° 50' N., longitude 44° 35' W. End of gale on the 14th, SW. Highest force of wind 12, WSW.; shifts not given.

**American S. S. Eastern Sailor:**

Gale began on the 14th, SW. Lowest barometer 29.65 inches at 11 a. m. on the 14th, S., 7; position, latitude 43° 53' N., longitude 17° 38' W. End of gale on the 15th, NNW. Highest force of wind, 10; shifts S.-W.-N. by W.

**American S. S. West Durfee:**

At 10 a. m. on the 14th, wind SSE., 5; barometer, 29.67 inches. Wind increasing; barometer falling slowly. 6:30 p. m., 29.39 inches (lowest), wind S. 10. 2 p. m. 15th, W. by S. 5; position at midnight on the 14th, latitude 30° 24' N., longitude 61° 50' W.

**Swedish S. S. Stockholm:**

Gale began on the 15th, SE. Lowest barometer 28.59 inches at 4 p. m. on the 15th, NW.; position, latitude 54° 32' N., longitude 36° 26' W. End at 8 p. m. on the 15th, NW. Highest force of wind 10, NW.; steady from NW.

**American S. S. West Wauna:**

Gale began on the 15th, S. Lowest barometer 29 inches at 1 a. m. on the 16th, WSW.; position, latitude 37° 35' N., longitude 54° 40' W. End of gale on the 16th, WNW. Highest force of wind 12; shifts SW.-WSW.

**American S. S. Sacandaga:**

Gale began on the 16th, SW. Lowest barometer 29.73 inches at 8 a. m. on the 16th, SW; position, latitude 36° 19' N., longitude 52° 23' W. End of gale at 4 p. m. on the 16th, NW. Highest force of wind, 10; shifts SSW.-W., 3 p. m. NW.

**British S. S. Swazi:**

Gale began on the 16th, S. Lowest barometer 28.87 inches at 9 p. m. on the 16th, SSW., 11; position, latitude 43° 40' N., longitude 44° W. End of gale on the 17th, W. Highest force of wind 12; shifts SSW.-SW.-WSW.

**Dutch S. S. Newyork:**

Gale began on the 17th, SSE. Lowest barometer 28.97 inches at 2 a. m. on the 17th, SSE.; position, latitude 45° 44' N., longitude 41° 06' W. End of gale on the 17th, WSW. Highest force of wind, 11; shifts S.-W.

**American S. S. Oregonian:**

Gale began on the 16th, SE. Lowest barometer 28.66 inches at 9 p. m. on the 16th, SW.; position, latitude 47° 30' N., longitude 42° W. End on the 17th, NW. Highest force of wind, 12; shifts SE.-NW.

**British S. S. Kenbane Head:**

Gale began on the 17th, SSW. Lowest barometer 29.75 inches at 6:30 a. m. on the 19th, SSW., 8; position, latitude 41° 30' N., longitude 54° W. End of gale on the 19th, SW. Highest force of wind 8, SSE.; shifts SSW.-SW.

**French S. S. Lafayette:**

Gale began on the 17th, SSW. Lowest barometer 29.47 inches at 6 p. m. on the 19th, SW., 5; position, latitude 48° 30' N., longitude 45° 43' W. End of gale on the 20th, NNW.; shifts not given.

**British S. S. Oxonian:**

Gale began on the 17th, SSW. Lowest barometer 29.41 inches at midnight on the 17th, SSW.; position, latitude 56° 48' N., longitude 25° 11' W. End of gale on the 18th, WNW. Highest force of wind 9; shifts SW.-WSW.

On the 19th there was a low over Newfoundland which probably moved in a northeasterly direction, although it was impossible to trace its track accurately on account of lack of observations. On the 22d its center could not have been far from Iceland, as on that day a barometric reading of 28.70 inches was recorded at Seydisfjord. Storm logs follow:

**British S. S. Winnebago:**

Gale began on the 19th, SSW. Lowest barometer 29.70 inches at noon on the 19th, SSW., 8; position, latitude 48° N., longitude 37° W. End of gale on the 20th, SW. Highest force of wind 8, SSW., steady from SSW.

**American S. S. Glen Ridge:**

Gale began on the 19th, SW. Lowest barometer 29.52 at 8 a. m. on the 21st, SW., 8; position, latitude 50° N., longitude 34° 15' W. End of gale on the 21st. Highest force of wind 8; steady from the SW.

**French S. S. La Lorraine:**

Gale began on the 20th, SW. Lowest barometer 29.85 inches at 7 a. m. on the 20th, SSW., 9; position, latitude 49° 40' N., longitude 25° 30' W. End of gale on the 21st, WNW. Highest force of wind 9, SSW.; shifts not given.

**British S. S. Adra:**

Gale began on the 20th, SW. Lowest barometer 29.58 inches at 6 p. m. on the 20th, S., 7; position, latitude 58° 30' N., longitude 15° 30' W. End of gale on the 20th, WNW. Highest force of wind 8; shifts S.-SSW.-SW.

**American S. S. Colquitt:**

Position at G. M. N. on the 20th, latitude 41° 23' N., longitude 42° 38' W. Noon to 4 p. m., heavy rain squalls, fresh SW. gale. Midnight to 8 a. m. on the 21st, fresh gale with squalls; barometer 29.91 to 29.86 inches.

Position at G. M. N. on the 21st, latitude 41° 50' N., longitude 37° W. At noon heavy rain; barometer 29.90 inches, southerly gale. 4 p. m., same, sky overcast, heavy sea. Between 4 and 8 p. m. gale increased to hurricane force during squalls; barometer steady at 29.96 inches.

**British S. S. Adra:**

Gale began on the 21st, SSW. Lowest barometer 29.45 inches at 6 p. m. on the 21st, SSW., 7; position, latitude 57° 25' N., longitude 20° 30' W. End of gale on the 23d, W. Highest force of wind 8; shifts SSW.-SW.-W.

From the 23d until the 29th moderate weather with uniformly high pressure prevailed over practically the entire ocean. On the 30th there was a slight depression central near latitude 47° N., longitude 37° W., and moderate northwesterly gales were reported from a very limited area, while light to moderate winds were the rule over the remainder of the ocean.

## ADDITIONAL NOTES ON THE HURRICANES OF SEPTEMBER, 1921.

There will be found on pages 522 and 523 of the REVIEW descriptions of the tropical hurricanes of September, the latter accompanied by a chart showing portions of the tracks of the two in existence between the 8th and 15th. In addition to the facts that have already been brought out in connection with these storms it is worth noting that the principal hurricane of the month, the one originating southeastward of the Windward Islands probably on the 7th or 8th, formed at a point unusually far south, about due east of the Island of Trinidad. In this respect it was similar to the hurricanes of June 23-27, 1831, and October 6-12, 1892, but these two storms moved on a course somewhat north of west, the former striking the Yucatan Peninsula, the latter the coast of Honduras. Hurricanes that have pursued courses comparable with the one under consideration were those of October 12-18, 1780, known as "The Great Hurricane," September 11-21, 1846, October 1-6, 1889, September 9-19, 1898, and September 8-17, 1908. It is not certain, however, that any of these originated as far to the southward as did the one of the present year or pursued such a long track after leaving tropical waters.

It has been suggested that the storm noted at Iceland on the 22d was in reality this so-called Windward Islands hurricane, which passed to the southeast of Newfoundland on the 17th, but the reports available do not clearly show this to be the case.

The first positive evidence of the existence of this hurricane was contained in a wireless message sent out at 8 a. m. of the 8th from the British S. S. *Dundrennan*, then about 150 miles south of Barbados. This message gave information of great value to many interests, as did several others received from various ships at different times during the progress of the storm. In the beginning the area affected by the hurricane was rather large and damage was caused at both Trinidad and Barbados. After passing the Grenadines, however, the area affected appeared to contract somewhat and to have again increased in size only after the storm reached the higher latitudes in mid-ocean.

Several vessels involved in this hurricane were in the calm center. The first of these was the American S. S. *West Faralon*, which on the 11th, at a point somewhat to the southward of the Mona Passage, was in the center for a period of 55 minutes, from 2.20 p. m. to 3.15 p. m. The lowest barometer reading recorded was 28.38 inches. On the 16th the American S. S. *Oswego* was in the center near latitude 41° N., longitude 53° W. The lowest barometer reading reported by the *Oswego* was 28.46 inches. On the 17th, from 12 to 12:30 a. m., the American S. S. *Capulin* was in the center near latitude 47° N., longitude 45° W. The lowest barometer observed on board this vessel was 28.32 inches. Capt. Henry A. Davis states in his report that "at midnight (16th-17th) the wind fell to a flat calm, sea without a ripple." A half hour later the wind freshened suddenly from NW. by N. and soon was blowing with hurricane force, high seas driving over the vessel.

Many vessels encountered this hurricane during its extended career and considerable damage to shipping resulted. Upward of 80 lives were lost and in the Windward Islands great numbers of people were rendered homeless.

On September 10, while the hurricane referred to was somewhat to the southeastward of the Mona Passage, a second center formed in the region immediately to the eastward of the Bahamas. The British S. S. *Camito*,

passing Grand Turk on the morning of the 11th, reported having encountered a hurricane 200 miles to the northward and was thought to have been in the center of it. On the 12th the American S. S. *Capillo* reported by wireless that she was involved in a hurricane to the southeast of Bermuda. This storm, which at first was of small size and fairly rapid movement, increased in size and also in rate of travel after passing Bermuda. It followed a path very similar to that of its successor north of latitude 30° and in mid-ocean was comparable to the latter in intensity. It was last observed on the 15th in latitude 53° N., longitude 35° W.

This secondary hurricane, so-called, was encountered by numerous vessels in the transatlantic steamer lanes and has been confused to some extent with its more important contemporary. It was this hurricane in which the French S. S. *La Savoie* was involved on the 14th-15th, this vessel, according to press dispatches, being forced to run before the wind for 18 hours and sustaining some deck damage. The Italian S. S. *San Pietro* was in the calm center of this hurricane from 5 a. m. to 5.30 a. m. of the 14th, the wind a dead calm but with a tremendous, confused sea. The lowest pressure observed on board the *San Pietro* was 28.90 inches.

Several westward-bound vessels encountered both this storm and the one which followed from two to three days later, thus having the exceptional experience of meeting two distinct hurricanes within the space of a few days.

Many excellent reports dealing with various phases of these storms have reached the Weather Bureau from masters and officers of vessels that were involved. Lack of space prevents giving these reports in detail. A number of storm logs will be found on pages 515-516.—F. G. T.

## NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Pressure conditions during September at the island stations of Dutch Harbor, Midway Island, and Honolulu were not marked by any extremes. At the first-named station there were frequent moderate changes in the barometer during the first and second decades, the average for these periods being close to the normal. During the last decade pressure averaged below normal by approximately 0.16 inch. At Midway Island pressure was slightly above normal, about 0.01 inch for the month, the barometer falling below the normal only on the 16th and 17th and from the 26th to the 30th. At Honolulu pressure averaged above normal by about 0.01 inch.

Unlike the North Atlantic, which was swept by several severe gales during the month, the North Pacific Ocean was relatively quiet during September. Occasional gales, mostly of a moderate character, were experienced by a few reporting vessels during the first and middle parts of the month. Only in the last four days was there any indication of renewed atmospheric activity in this ocean.

From the 1st to the 3d the Japanese S. S. *Horaisan Maru*, Capt. K. Yamaguchi, Observer M. Okhara, Muroran for San Francisco, was involved in a gale in latitude 50° 30' N., longitude 177° E. to 174° W. The highest force of wind experienced was 8, SE. From the 12th to the 14th, in the same region, the Japanese S. S. *Lyons Maru*, Capt. S. Fujimura, also from Muroran for San Francisco, had a moderate to whole gale with a very high sea. This appears to have been the most important gale of the month in the northern part of the ocean,

with the exception of the one of the 26th to 30th. Several reporting vessels were involved in the latter storm, of which the following may be named:

American S. S. *Granite State*, Capt. H. Wallis, Observer F. H. Spring, Calcutta for San Francisco; U. S. Army transport *Dix*, Capt. C. A. Olsen, Observer O. C. Radford, Manila, via Miike, for Honolulu; U. S. Army transport *Thomas*, Capt. Frank Hall, Observer A. B. Taylor, Manila, via Miike, for Honolulu; Japanese S. S. *Toyooka Maru*, Capt. S. Oya, Observer M. Takahara, Yokohama for Seattle; American S. S. *Nanking*, Capt. T. H. Dobson, Observer A. A. Wahldram, Yokohama for San Francisco. The highest force of wind reported by any of the vessels named was 10, ENE., by the *Dix*. This was on the 29th in latitude 30° 02' N., longitude 180°. At 1 a. m. of the 29th *Dix* had the lowest barometer reported, 29.39 inches.

On several occasions during the month vessels on coast-wise routes north from Panama reported E. to SE. gales. The most important of these seems to have been that of the 25th and 26th. This was encountered by the American S. S. *Hattie Luckenbach*, Capt. Edward J. Boe, Observer Edward E. Krayn, Panama for San Pedro. The storm log is as follows:

Gale began on the 25th; lowest barometer, 29.72 inches, occurred at 4 p. m., same date, in latitude 19° 35' N., longitude 105° 05' W.; end of gale on 26th; highest force of wind, 9, SE.; shifts, SE., ESE., SE.; high, irregular sea.

A strong breeze with a rough sea continued on the 27th and 28th, until the vessel reached about latitude 26° N.

### THREE TYPHOONS IN THE FAR EAST DURING SEPTEMBER, 1921.

By JOSÉ CORONAS, S. J., Chief Meteorological Division.]

[Weather Bureau, Manila, P. I., October 18, 1921.]

Following is a brief account of the three most important typhoons of this month of September:

The first was a China Sea typhoon, the second was a Formosa typhoon, and the third a Japan typhoon. The second must have passed also over or very close to the Batan Islands in the Philippines; but it is much regretted that owing to lack of communications with those islands no word has been as yet heard from them at the time we are writing these notes (October 17).

*China Sea typhoon, September 1 to 4.*—This typhoon was formed on the 1st of September in the neighborhood of the Paracels in about 113° longitude E. and 16° latitude N. It moved practically northward and entered China about 150 miles west of Hongkong in the evening of the 3d. No details have been received of any big damage done by this typhoon. The British steamer *Loonsang* experienced a gale from the southeast quadrant on her way from Hongkong to Manila on September 3.

*Formosa typhoon, September 14.*—This typhoon was noticed on our weather maps as forming on the 7th to 8th about 300 miles west of Yap near 133° longitude E. and 9° latitude N. It took a northwesterly direction and reached the southern part of Formosa during the night of the 13th. The approximate position of the typhoon at 6 a. m. of the 12th and 13th was, respectively, 126° longitude E., 18° latitude N., and 123° 30' longitude E., 20° latitude N. The typhoon traversed the western part of Formosa and the northern part of Formosa Channel, moving practically north. Then it recurved westward and entered China near Foochow during the night of the 14th to 15th. The barometric minimum

recorded in Formosa was that of Taito, 741.00 mm.<sup>1</sup> (29.17 ins.) at 12 midnight of the 13th.

Although it was a well-developed typhoon not much damage was done in Formosa according to a report received from the Director of Taihoku Observatory.

*Japan typhoon, September 25.*—This typhoon seems to have formed on the 21st to 23d to the northeast of Luzon in about 127° 30' longitude E. and 20° latitude N. It moved NNE. and crossed Japan during the night of the 25th. Once in the Sea of Japan it recurved northwest toward Manchuria. The approximate position of this typhoon was as follows on the 24th, 25th, and 26th:

September 24, noon, 23° 25' latitude N., 130° 40' longitude E.  
September 25, noon, 29° 05' latitude N., 134° 20' longitude E.  
September 26, 6 a. m., 37° 45' latitude N., 135° 50' longitude E.

According to press dispatches published by the Manila papers much damage was done in Japan by the winds, rains, and floods during this typhoon.

### SQUALLS IN GULF OF FONSECA.

E. F. McCartin, U. S. N., acting as meteorological observer on board the U. S. S. *Cleveland*, which for some days during September was in the harbor of Amapala, Honduras, has furnished the following note regarding the squalls which occur at that place.

In Amapala, Honduras, the barometer usually drops sharply as temperature increases up to 1 p. m. Violent squalls at sunset are frequent, sometimes reaching a wind force of 9 and lasting from 15 to 30 minutes. They are accompanied by heavy rain and a sharp drop in temperature. These squalls usually develop at the northeastern end of the Gulf of Fonseca and travel to seaward.

### THREE SUCCESSIVE TYPHOONS OVER THE PACIFIC BETWEEN THE PHILIPPINES AND JAPAN, AUGUST 1 TO 20, 1921.

By JOSÉ CORONAS, S. J., Chief Meteorological Division.

[Weather Bureau, Manila, P. I., July 30, 1921.]

Very stormy weather prevailed over the Pacific between the Philippines and Japan for no less than 20 successive days, August 1 to 20, owing to three severe typhoons which moved one after another from the Western Carolines or the Ladrone Islands to the China coast between Hongkong and Shanghai.

Once more we could realize in the three cases the great importance of the two daily weather reports we are receiving at present from our advanced stations of Yap and Guam. With these observations at hand, Manila Observatory was able to announce the first typhoon on August 2, four days before it reached Formosa; and the second and third, on August 8 and 10, 6 and 10 days, respectively, before they reached the China coast to the south of Shanghai. For the whole period of 20 days we were able to broadcast typhoon warnings by wireless and cable, following day by day the tracks of the three typhoons.

*The Formosa and China typhoon, August 1 to 7.*—This typhoon appeared in our weather maps as forming over the Western Carolines to the E. of Yap and SSW. of Guam, on August 1 near 10° latitude N. and 143° longitude E. For about three days the typhoon seems to have moved NW., then it moved almost due W. for over one day, and on the 5th it took again a northwesterly

<sup>1</sup> 739.6 mm. (29.12 ins.) gravity correction applied.

direction toward Formosa, crossing the southern part of this island in the afternoon of the 6th. At about midnight of the same day it entered China between Foochow and Formosa. The position of the center at 5 p. m. of the 6th was near  $120^{\circ}$  longitude E. and  $23^{\circ} 40'$  latitude N. From reports received from Taihoku Observatory, we know that the minimum barometric reading observed in Formosa during the typhoon was 731.5 millimeters (28.80 inches) as recorded at Taito, a station on the southeastern coast of the island. The losses caused by the storm throughout the island were: Persons killed 3, injured 28; houses totally wrecked 1,029, partly wrecked 2,890.

*The typhoon of the Loochoos and China, August 6 to 14.*—This typhoon was shown in our weather maps as forming on the 6th to 7th to the NW. of Guam near  $142^{\circ}$  longitude E. and  $16^{\circ}$  latitude N. It moved first almost due W. for two days, then northward for nearly two days until in the afternoon of the 10th it took again a westerly direction toward China. The center passed on the evening of the 10th very close to Naha, Okinawa Island, where the barometer fell to 721.4 millimeters (28.40 inches) at 6 p. m. of that day. Great damage was done to the island according to telegraphic reports received at Formosa. It took over two days for the typhoon to cross the Eastern Sea and reach the China coast, from the afternoon of the 11th to the early morning of the 14th. The approximate position of the center at 6 a. m. of the 14th was  $120^{\circ} 35'$  longitude E. and  $27^{\circ} 55'$  latitude N.

The steamship *Shinano Maru*, which had left Keelung on the 11th, encountered this typhoon in the Eastern Sea; she reached Moji a day and a half later after experiencing a heavy storm. Hurricane easterly winds were also experienced on the 13th in the Eastern Sea by the steamship *Aki Maru*, on her way from Nagasaki to Hongkong, the

minimum barometric reading observed on board having been 28.91 inches.

*The typhoon of the Bonins and China, August 10 to 21.*—It is impossible in this case to ascertain whether this typhoon formed far to the east of the Ladrone Islands, as we have no observations from the Pacific to the E. or NE. of Guam. Our weather maps of the 10th showed this typhoon to the NE. or NNE. of Guam near  $148^{\circ}$  or  $149^{\circ}$  longitude E. and  $18^{\circ}$  latitude N. After moving slowly to WNW. and NW. from the 10th to 12th it took on the 13th a straight northerly direction toward the Bonin Islands which it reached in the early morning of the 15th. The barometer fell to 730.5 millimeters (28.76 inches) at Chichijima, at 6 a. m. of that day (we do not know as yet the exact minimum observed during the typhoon). The approximate position of the center at that time was  $141^{\circ} 45'$  longitude E. and  $26^{\circ} 30'$  latitude N. After traversing the Bonin Islands, the typhoon took suddenly and unexpectedly an approximate westerly direction, thus threatening again the Eastern Sea and the China coast near Shanghai. The approximate positions of the typhoon at 6 a. m. of the 18th, 19th, and 20th are as follows:

August 18, 6 a. m.:  $130^{\circ}$  longitude E.,  $29^{\circ} 55'$  latitude N.

August 19, 6 a. m.:  $127^{\circ} 25'$  longitude E.,  $29^{\circ} 45'$  latitude N.

August 20, 6 a. m.:  $123^{\circ} 15'$  longitude E.,  $29^{\circ} 30'$  latitude N.

The typhoon seems to have entered China about 80 miles to the south of Shanghai. According to the telegraphic reports published in Manila papers, the Blue Funnel liner *Glaucus* and the Messageries Maritimes mail steamer *Cordillere* went aground in the Yangtse River near Shanghai during the typhoon.

#### NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

*British Isles.*—The rainfall of the month was below the average over practically the whole of the British Isles. \* \* \* In London (Camden Square), the mean temperature was  $60.5^{\circ}$  F., or  $2.8^{\circ}$  F. above the average. This was the thirteenth successive month with mean temperature in excess of the average of the 60 years 1860-1919.—*Meteorological Magazine*, Oct., 1921, p. 276.

*Portugal.*—Lisbon, September 24: Another terrific thunderstorm swept Portugal yesterday, torrential rains falling in many parts of the country. \* \* \* In some quarters of this city, the water was more than 10 feet deep, and the people living there were rescued with difficulty.

East of Lisbon incalculable damage was done in the agricultural provinces, especially in vineyard sections and several people were killed by lightning.—*New York Times*, Sept. 25, 1921.

*Italy.*—Rome, September 22: From depressing heat Rome has suddenly been transformed into a city of shivering cold. A cloudburst occurred yesterday, accompanied by a storm of hail which covered the streets in some places 6 inches deep.—*New York Evening Mail*, Sept. 23, 1921.

*China.*—Shanghai, September 6: China's third great disaster within a year has been recorded in Anhwei Province, where an area larger than the State of Connecticut has been flooded, with the loss of thousands of lives

and property damage conservatively estimated at \$80,000,000. The inundation occurred when Hungtze Lake and some of its tributary rivers overflowed.—*New York Evening World*, Sept. 27, 1921.

*Japan.*—Tokio, September 28: Several hundred persons have been killed by a typhoon in Central Japan centering upon Nagoya, on the island of Hondo, where a tidal wave destroyed crops and houses. Several steamers were sunk and many fishermen are missing.—*New York Journal of Commerce*, Sept. 29, 1921.

*Argentina.*—Buenos Aires, September 15: The unusual phenomenon of an almost unbroken winter-long drought, which caused serious concern for the crop prospects of Argentina, has been ended by good rains which fell yesterday and to-day in many sections of the country.—*Washington Star*, Sept. 17, 1921.

*South Africa.*—London, September 12: The worst blizzard in many years has been raging for some days over the greater part of the Orange Free State, Natal, and portions of Cape Colony and the Transvaal, says a dispatch from Capetown to-day.

Pietermaritzburg, capital of Natal, was cut off from rail, telegraph, and telephone communication with the north for some days. In some parts of the Transvaal, the snowfall lasted 15 hours, an unprecedented occurrence.—*Washington Post*, Sept. 13, 1921.

## DETAILS OF THE WEATHER IN THE UNITED STATES.

## GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

The larger features of the weather of the current month were (1) relatively low atmospheric pressure except in the extreme southeast and the extreme northwest; (2) a return to the type of temperature distribution which prevailed in the early summer months; (3) torrential rains in southwestern Texas, very generous rains over Missouri, eastern Iowa, northwestern Illinois and southwestern Wisconsin, and about normal rains in Washington and Oregon. In other parts of the country drought prevailed, though not especially marked except in the Florida peninsula.

## CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

The number of low-pressure areas plotted considerably exceeded the normal, but they moved, as a rule, in high latitudes. Indifferent air pressure within the Tropics resulted in the formation of three hurricanes, not included in the tables, but plotted on Chart III and numbered V, VI, and IX, respectively. These storms were of small diameter, but of the greatest intensity.

High-pressure areas, budding off from the north Pacific high, were three times as frequent as the normal, while the two highs originating in the interior north of Alberta, though reinforced, were not important in reducing the temperature except in the northern Rocky Mountain region. The movement and character of the highs and lows were favorable for warm weather over eastern districts.

Tables showing the number of highs and lows by type follow:

LOWs.	Al- berta.	North Pa- cific.	South Pa- cific.	North- ern Rocky Moun- tain.	Colo- rado.	Texas.	East Gulf.	South At- lantic.	Central.	Total.
September, 1921.	5.0	.....	1.0	.....	5.0	.....	.....	2.0	4.0	17.0
Average number, 1892-1912, inclusive.....	4.1	1.1	0.4	0.6	0.7	0.3	0.4	0.2	0.7	8.5

HIGHs.	North Pacific.	South Pacific.	Al- berta.	Plateau and Rocky Moun- tain region.	Hudson Bay.	Total.
September, 1921.	6.0	.....	2.0	2.0	2.0	12.0
Average number, 1892-1912, inclusive.....	2.1	1.0	3.5	0.7	0.6	7.9

## THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Nov. 1, 1921.]

## PRESSURE AND WINDS.

As has been the case for a number of months past, pressure changes were usually moderate in degree and a general stagnation of the atmospheric circulation existed during long periods over the southeastern districts, where the pressure continued somewhat higher than normal.

Along the northern border cyclonic areas were noted at frequent intervals, though in most cases they affected rather small areas.

Anticyclones entered the country mostly from the north Pacific coast and, drifting slowly eastward over the central and southern districts, produced, as is usually the case, no important temperature changes. In two instances, however, anticyclones entered the United States from the Canadian Northwest and in their movement southward brought the most important temperature changes of the month. The first, about the 10th to 13th, overspread the western mountain and Plateau districts, and the second, a combination north Pacific and Canadian high area, materially lowered the temperatures over most western and central districts on the last two days of the month.

The average pressure for the month was slightly above 30.05 inches over the Southeastern States and a small area having similar pressure existed in the extreme Northwest. Average pressure was below 29.95 inches along the northern border from Montana eastward.

Save over the Southeastern States and locally along the Pacific coast, and in the far Northwest, pressure was below normal in all portions of the United States and in Canada also, as far as observations disclose.

The diminishing pressure from the southeastern districts toward the northern border favored a continuation of southerly winds over practically all districts from the Rocky Mountains eastward, which conditions have been noted so prominently during much of the present year.

The principal period with high winds over an extended area was on the last day of the month, in connection with the movement of a cyclonic area of considerable force over the Great Lakes. At Buffalo, N. Y., a velocity of 78 miles per hour was registered on that date, the second highest velocity ever recorded at that station in September. In other portions of the country high winds were local and usually occurred in connection with thunderstorms.

## TEMPERATURE.

The outstanding feature of the weather of the month was a continuation of the abnormal warmth that has persisted to such an unusual extent over much of the country east of the Rocky Mountains during the present year, and over considerable areas unusual warmth has prevailed even farther back into the latter part of the preceding year. In fact portions of the upper Mississippi Valley and Great Lakes regions have had monthly mean temperatures constantly above normal for the past 13 months. The high monthly means of temperature were due to continued warmth throughout the month and not to periods of unusually high temperatures, some portions of Southeastern States having daily temperatures above the normal throughout the entire month.

No portion of the month had outstanding temperatures that marked the culmination of a heated period, but the maximum temperatures were distributed through all the periods in some portion of the country, although the first few days were warmest over most central and eastern districts.

While protracted heat dominated the eastern two-thirds of the country, a marked reaction to cooler weather existed in the far West, particularly in the northern Plateau and Rocky Mountain sections, where the month was nearly as continuously cool as it was warm in the more eastern districts.

Minimum temperatures in the northern Plateau region about the 11th to 13th were in some localities the lowest of record for September, and killing frosts were the earliest ever known. Also near the end of the month temperatures were again quite low, extending eastward into the Great Plains and central valleys at the close.

For the month as a whole temperatures averaged above normal in all districts from extreme southern California to the Dakotas and thence eastward to the Atlantic, and over a narrow strip along the immediate Pacific coast.

Over many of the eastern and southeastern portions of the country the month was the warmest September in more than 50 years, and in New England the record at New Haven, Conn., extending back 143 years, shows only one September with a higher mean. Over the Plateau and central and northern portions of the Rocky Mountains the month was from 3° to 6° cooler than normal, and at points in Idaho, eastern Oregon, and western Montana, it was the coldest September of record.

Maximum temperatures were above 100° in most of the Central and Southern States, and in the Plains region they were observed as far north as the Dakotas.

Minimum temperatures were not below the freezing point over the greater part of the country east of the Great Plains, and no killing frosts occurred except along the northern border. In the far Northwest killing frost occurred about the beginning of the second decade, and at the lower elevations of the Rocky Mountains and over the Great Plains it was delayed till the close of the month.

#### PRECIPITATION.

Rainfall during the month was, as a rule, poorly distributed both in amount and in the times of occurrence.

Over the Ohio and upper Mississippi Valleys and Great Lakes region, precipitation was too frequent and heavy, particularly during the first and second decades, while along the Atlantic coast and over the Gulf States as far west as Texas and generally from the central Plains to the Pacific it was infrequent and light. In Texas unusually heavy rains occurred near the end of the first decade, the amounts at some points exceeding 20 inches

in 24 hours, the heaviest ever reported in the United States in that period of time. A full account of this and the attending loss of life and damage to property from the resulting floods will be found in another portion of this REVIEW. Over the far Southwest some unusually heavy rains for that region occurred on the last day of the month, and good rains occurred in the far Northwest during the latter part of the second and the early part of the third decades.

For the month as a whole precipitation was above normal over the Plains region from Texas to the Canadian border and eastward to the Ohio Valley and Great Lakes, and in portions of the far Northwest. Along the Atlantic coast from Maine to Florida, precipitation was insufficient for agricultural needs, and similar conditions were rather general in the Gulf States except eastern Texas. In Florida the precipitation was barely one-third the usual fall for September and at points the month was one of the driest in 50 years.

#### SNOWFALL.

On the 9th and 10th of the month an unusual snow-storm, for so early in the season, occurred in the mountain portions of central Montana, where depths up to nearly 15 inches were reported. In a few other districts snowfall was reported but only for the highest elevations.

#### RELATIVE HUMIDITY.

The drought conditions over the Atlantic and Gulf coast were definitely outlined by the negative departures of the relative humidity of the month as compared with the normal, while the excesses over the Mississippi and Ohio Valleys show the regions of heavy and frequent precipitation.

From the Great Plains westward to the Pacific the relative humidity was very generally less than the normal, although in the far Southwest heavy rains increased the relative moisture content of the air and in the far Northwest the continued cool weather had the same effect.

#### STORMS AND WEATHER WARNINGS.

Edward H. Bowen, Superintending Forecaster.

#### WASHINGTON FORECAST DISTRICT.

West Indian hurricane of Sept. 8 to 15.—This disturbance made its appearance the morning of the 8th to the southward of Barbados, traveled west-northwestward and crossed the Grenadines during the night of the 8th and passed on to the Caribbean Sea. Its course from the Grenadines was west-northwest and the afternoon of the 10th it was encountered by the steamship West. It was in approximately lat. 17° N. and long. 65° W. when the barometer fell to 28.35 inches with winds of hurricane force. Passing northward from this position its center crossed Haiti and then pursued a northerly course passing the Bermudas on the 15th and what seemed to be this storm was in the vicinity of Iceland on the 25th. The disturbance was of rather small diameter but of great intensity throughout its course. It is reported to have caused considerable damage to shipping, buildings, and crops and to have caused the loss of a number of lives in the eastern islands of the West Indies and the Bermudas.

On the morning of the 8th, when the signs of the approach of this hurricane were unmistakable, the following observations were made:

San Juan, Porto Rico. Tropical storm of moderate intensity with center south of the island of Porto Rico, moving west-northwest, with probable passage to the north of the island of Porto Rico during Friday, the 9th. Further information will be given about 7 p. m.

Based on 1 p. m. special observations from eastern Caribbean stations the following warning was issued by the district forecaster at San Juan, Porto Rico:

A tropical storm of moderate intensity with center south of the island of Porto Rico, moving west-northwest, will probably pass to the north of the island of Porto Rico during Friday, the 9th. Further information will be given about 7 p. m.

Atmosphere of the 9th the district forecaster at San Juan, Porto Rico, issued the following warning:

One forecast. Tropical storm center about 300 miles southwest of San Juan, Porto Rico, at noon, moving west-northwest at rate of 12 miles an hour. Probable to strong winds with rain probable along coast of Porto Rico tonight.

At 8 a. m. of the 10th the following information was issued by the district forecaster at San Juan, Porto Rico:

Tropical storm apparently increased in area and extent during the night and continued its movement west-northwest. This morning the center was about 300 miles southwest of Porto Rico; squalls and heavy rain were noted during the night and early morning in Porto Rico, but the island is now out of the danger zone.

It was concluded that the storm had its center in the vicinity of the island of Porto Rico and that it was moving west-northwest.

## SEVERE LOCAL STORMS.

The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
Waxahachie, Tex. (west of)...	1	P. m.				Small cyclone....	Considerable property damage.....	Dallas Morning News (Dallas, Tex.).
Washington, D. C.....	2	P. m.		3		Electrical and rain.	Slight property damage.....	Washington Herald (Washington, D. C.).
Plattsville, Wis., and vicinity.	4					Electrical, rain and wind.	Floods and wind caused destruction of thousands of acres of corn; barns and trees struck by lightning; much damage to newly constructed highway.	Times-Journal (Dubuque, Iowa).
Austin, Tex., and vicinity...	9	P. m.				Tornado.....	Buildings and wires slightly damaged; considerable property damage at Creedmoor.	Dallas Morning News (Dallas, Tex.).
Nixon, Tex. (west of).....	9		20			Wind.....	Crops, buildings, etc., in path destroyed.....	San Antonio Daily Express (San Antonio, Tex.).
Milano, Tex.....	9	P. m.	25 to 30			do.....	General damage done.....	Do.
St. Louis, Mo.....	9	1.30 p. m.			\$15,000	Thunderstorm.....	Street car and electric light service impaired; a number of buildings struck by lightning; cellars flooded.	Globe-Democrat (St. Louis, Mo.).
Bartlett, Tex.....	10-11					Rain.....	Severe damage suffered by railways, bridges, and crops; telephone communication cut off.	Dallas Morning News (Dallas, Tex.).
Marmarth, N. Dak.....	12					Wind.....	Several buildings wrecked.....	Fargo Forum (Fargo, N. Dak.).
Anoka, Minn., and vicinity..	20	P. m.				Hail, wind, and rain.	Heavy damage to crops and buildings.....	Washington Herald (D. C.).
Zanesville, Ohio.....	21					Wind.....	Business section suffered severe losses.....	Daily News (Chicago, Ill.).
Belair, Ohio (west of).....	21					Rain.....	Homes flooded, corn crop destroyed, and live stock drowned.	Do.
Buffalo, N. Y.....	21	P. m.				Rain and hail.....	Minor damage.....	Express (Buffalo, N. Y.).
Grand Haven, Mich.....	21					Wind.....	Much damage by high winds to trees, wires, etc.	Weather Bureau official.
Madison, S. Dak.....	21				10,000	Hail.....	Severe general damage; 3-inch hailstones fell.....	Herald-Examiner (Chicago, Ill.).
Mint Springs, Va. (Augusta County).....	22		10		5,000	Small tornado.....	Damage principally to buildings and trees; 2 injured.	Weather Bureau official.
Buffalo, N. Y.....	22					Gale.....	Velocity of wind 60 miles; no damage reported.	Express (Buffalo, N. Y.).
New Orleans, La.....	25	P. m.			10,000	Electrical.....	Severe damage to power station; street car lines tied up for 3 hours.	Times-Picayune (New Orleans, La.).
Terre Haute, Ind.....	29	P. m.	16 to 50		10,000-15,000	Thunderstorm and wind.	Severe damage by wind; 4 persons injured.....	Weather Bureau official.
Scranton, Pa.....	30	P. m.				Wind.....	Industries generally temporarily crippled; most damage suffered by power-carrying apparatus.	Washington Herald (Washington, D. C.).
Buffalo, N. Y., and vicinity..	30			1		Wind and thunderstorm.	Buildings leveled and much damage in fruit belt along south shore of Lake Ontario; velocity of wind 74 miles.	Washington Post (Washington, D. C.).
Cleveland, Ohio, and vicinity.	30			5		Wind.....	Property damaged to the extent of thousands of dollars; no serious damage in Cleveland; wind 50 to 74 miles.	Plain Dealer (Cleveland, Ohio).
Western New York, Pennsylvania, and Lower Lake region.	30			2		Gale.....	Severe windstorm causes heavy damage to property, crops, etc.; fires caused by lightning; velocity of wind 78 miles.	New York Times (New York, N. Y.).
New York City, N. Y.....	30	P. m.				Wind.....	Minor damage; cellars flooded; 52-mile wind....	Democrat Chronicle (Rochester, N. Y.).
Dayton, Ohio.....	30				19,800	Electrical.....	"Baby blimp" dirigible balloon and hangar destroyed; 1 person seriously injured.	Do.
Rochester, N. Y.....	30					Heavy gale.....	Great damage wrought to apple crop; thousands of bushels blown off.	Weather Bureau official.

## STORMS AND WEATHER WARNINGS.

EDWARD H. BOWIE, Supervising Forecaster.

## WASHINGTON FORECAST DISTRICT.

*West Indian hurricane of Sept. 8 to 15.*—This disturbance made its appearance the morning of the 8th to the southeastward of Barbados, traveled west-northwestward and crossed the Grenadines during the night of the 8th and passed on to the Caribbean Sea. Its course from the Grenadines was west-northwest and the afternoon of the 10th it was encountered by the steamship *West Faralon* in approximately Lat. 17° N. and Long. 68° W., when the barometer fell to 28.38 inches with winds of hurricane force. Passing northwestward from this position its center crossed Haiti and then pursued a northerly course, passing the Bermudas on the 15th and what seemed to be this storm was in the vicinity of Iceland on the 22d. The disturbance was of rather small diameter but of great intensity throughout its course. It is reported to have caused considerable damage to shipping, buildings, and crops and to have caused the loss of a number of lives in the eastern islands of the West Indies and the Bermudas.

On the morning of the 8th, when the signs of the approach of this hurricane were unmistakable, the fol-

lowing warning was issued by the district forecaster at San Juan, Porto Rico:

Tropical disturbance east of the island of Trinidad at 8 a. m., probably moving west-northwest. Caution advised through eastern Caribbean Sea. Further information will issue about 3 p. m.

Based on 1 p. m. special observations from eastern Caribbean stations the following warning was issued by the district forecaster at San Juan, Porto Rico:

1 p. m., tropical storm of moderate intensity with center south of the island of Barbados, moving west-northwest, will probably pass to the south of the island of Porto Rico during Friday, the 9th. Caution advised throughout the eastern Caribbean Sea area. Further information will issue about 10 p. m.

At noon of the 9th the district forecaster at San Juan, Porto Rico, issued the following warning:

Noon broadcast. Tropical storm center about 200 miles southeast of island of Porto Rico at noon, moving west-northwest at rate of 12 miles an hour. Moderate to strong winds with rain probable along south coast of Porto Rico to-night.

At 8 a. m. of the 10th the following information was issued by the district forecaster at San Juan, Porto Rico:

Tropical storm apparently increased in area and extent during the night and continued its movement west-northwestward. This morning the center was about 300 miles southwest of Porto Rico; squalls and heavy rains occurred during the night and early morning in Porto Rico, but the island is now out of the danger zone.

These and other warnings issued by the San Juan station and the Central Office were disseminated to West Indian stations and to stations on the Gulf and Atlantic coasts. They were also sent by Navy Radio to vessels at sea.

On Sunday, the 11th, when there were indications that this disturbance was moving northward over Haiti, the following advisory information was issued from the Central Office:

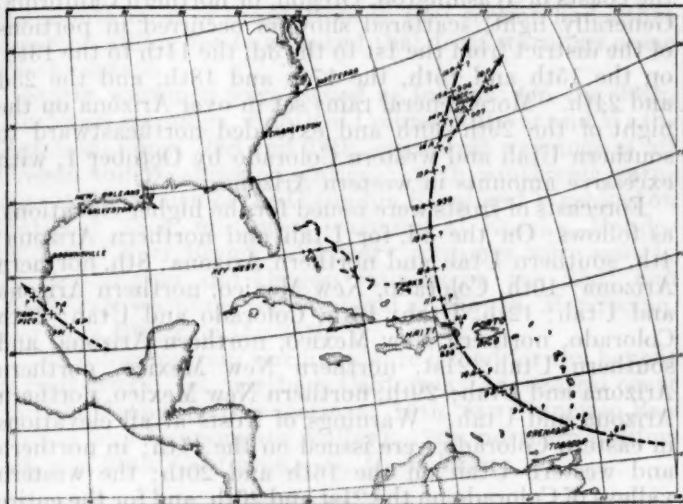


FIG. 1.—Path of hurricane of Sept. 8-15, 1921.

Advisory, 10 p. m. Tropical storm has moved northward and to-night its center is over northwestern Haiti. Future movement uncertain but probably northward. Shifting gales over and to eastward of the Bahamas during the next 36 hours.

This disturbance, as stated in the opening paragraph, moved northward from Haiti, and on the morning of the 14th notification was sent the Bermudas that the disturbance was moving northeastward toward these islands. Its center passed near the Bermudas the morning of the 15th, when the pressure fell to near 29 inches with winds of hurricane force.

The night of the 15th the following communication was sent the Office of Naval Communications, Navy Department, Washington, D. C.:

Please broadcast the following tonight: "Storm of hurricane intensity moving northeastward from the vicinity of Bermudas. It will pass onto transatlantic steamship lanes during Friday and continue to move eastward with unabated intensity."

As previously stated this storm was apparently the one charted over Iceland the morning of the 22d, when the barometer stood at 28.70 inches with wind of gale force. It is a remarkable coincidence that at the time the southern hurricane was centered north of Haiti that the steamship *Capillo* reported by radio having encountered on the 12th a hurricane of small diameter, barometer below 29 inches, near and immediately southeast of the Bermudas, moving rapidly northeast. This disturbance was separate and distinct from the primary disturbance herein referred to. Moreover, immediately preceding the appearance of the tropical storm in the eastern Caribbean Sea, there were signs of a disturbance over the southwest Gulf of Mexico, as indicated by reports by radio from vessels in that region. It passed on to the Mexican coast during the 7th and was dissipated, but there is reason to believe that the phenomenal rains in southern Texas on the 9th and 10th were associated with this disturbance. Conceding that the disturbance that appeared on the 8th southeast of Barbados was in existence previously to that date, it follows that from

the 6th to 14th there were three storms of a tropical nature over the southern waters at approximately the same time.

The paths of these disturbances will be found elsewhere in this number of the REVIEW.

In the Washington Forecast District no storm warnings were issued or required for the east coast of the Gulf of Mexico and for the Atlantic coast south of Cape Henry.

*For the Atlantic coast north of Cape Henry.*—Southwest storm warnings were ordered on the 11th for the coast at and north of Delaware Breakwater, when a disturbance of marked intensity was over the Great Lakes and moving northeastward, and strong winds, at times reaching gale force, occurred over the stretch of coast where warnings were displayed. On the 25th southwest storm warnings were displayed on the coast at and north of Delaware Breakwater when a disturbance of considerable intensity was centered north of the Great Lakes and moving eastward toward the St. Lawrence valley, and it was attended by strong south shifting to west winds during the night of the 25th along the coast north of Sandy Hook. On the 30th southwest storm warnings were displayed on the coast between the Virginia Capes and Eastport, Me., when a disturbance of marked intensity was central over the Great Lakes and moving eastward; the conditions forecast occurred along the coast covered by warnings, the maximum velocity being 56 miles an hour from the south at New York City.

*On the Great Lakes.*—Storm warnings were displayed on one or more of them on the 17th, 20th, 21st, 25th, 26th, 28th, 29th, and 30th. On the 17th the display was that of southwest warnings on Lakes Erie, Huron, and Ontario, when a disturbance of considerable intensity had its center north of Lake Superior. On the 20th the display was for strong south to west winds on Lakes Erie, Huron, Michigan, and Superior except the extreme west portion, the disturbance at the time of the display being central north of Minnesota, and on the morning of the 21st the display of southwest warnings was extended to Lake Ontario. The disturbance on the morning of the 21st was central north of Lake Superior and moving east-northeastward. It was attended by strong south to west winds and gales over the entire region of the Great Lakes. The morning of the 25th northwest storm warnings were displayed on Lakes Huron, Erie, and Ontario, when a disturbance of considerable intensity was central north of Lake Huron and moving eastward. This disturbance produced northwest gales on Huron and extreme eastern Superior, but no winds of consequence elsewhere. On the evening of the 28th northwest storm warnings were displayed on western Lake Superior, and the morning of the 29th southwest warnings were ordered for eastern Lake Superior and for Lakes Michigan, Huron, and Erie, and on the morning of the 30th for Lake Ontario, in connection with a disturbance of the Alberta type. This disturbance increased markedly in intensity during the night of the 29th, and during the 30th it was attended by general gales on the Great Lakes, except western Lake Michigan. The maximum wind velocity reported was 76 miles from the southwest the afternoon of the 30th on extreme eastern Lake Erie.

No abnormally cold weather occurred in the Washington Forecast District during the month, although frosts occurred during the third decade at a number of points along the northern border.

#### CHICAGO FORECAST DISTRICT.

Fire-weather warnings and forecasts were continued to the district forester at Missoula, Mont., for distri-

bution to the National Forests until September 8, when they were terminated because of the general rains which set in over the State on that day and night, making the warnings no longer necessary.

Fire-weather warnings were sent to the forest supervisor at Cass Lake, Minn., from September 7 to 9, inclusive, for use of the National Forest in that vicinity; and to the State forester at St. Paul, Minn., beginning with September 29 for distribution to the State forests under his supervision.

Because of the unseasonably warm weather during the month of September general frost warnings were not necessary. They were, however, sent to the northwestern States on several days where the temperature was low as compared with other portions of the Chicago District. These warnings were, as a rule, fully verified.

While the temperature in the Wisconsin cranberry-marsh region was considerably above the normal during most of the month, nevertheless frost warnings were necessary upon several dates. By the end of the month the crop had been harvested in practically all the marshes and the growers gave the usual credit to the Weather Bureau for its advices, which made it possible for them to flood their properties in advance of all critical temperatures. As a consequence there was no loss suffered through frosts.

Several letters have been received from the growers testifying as to the value of the warnings and extracts are given from two of these.

Mr. C. L. Lewis, manager of the Badger Cranberry Co., Beaver Brook, Wis., writes as follows:

I have just completed my harvest for 1921 and am glad to report that I have now under cover a very nice crop which will amount to about 1,800 barrels, with a very good price in prospect. Mr. Colton is also through and we will not need further frost warnings this season.

I will take this occasion to thank you for the valuable service that you have rendered us during the season just passed, and I hope that you may favor us with a visit during the coming year so that we may show you how we have progressed since you were last here.

Mr. Alexander E. Grimshaw, of Mather, Wis., sends the following contribution:

These warnings are distributed as soon as received by means of telephone service and are sent over the several lines whereon the marshes are situated. The value of this service can not be overestimated. Many times in event of sudden changes and severe frosts these warnings have been the means of saving the crops and have resulted in the savings of thousands of dollars. It would be looked upon as a great calamity to all growers of cranberries should the service be discontinued.—H. J. Coz.

#### NEW ORLEANS FORECAST DISTRICT.

The weather was free from damaging winds on the Texas and Louisiana coasts and was unusually warm. Neither storm warnings nor frost warnings were issued or required, but a warning of northerly gales at Tampico, Mexico, was issued on the morning of the 7th, in connection with a moderate tropical disturbance, and was justified.

The feature of the month was the torrential rainfall in central and southwestern Texas on the 8th-10th, due to the tropical disturbance which passed Tampico on the 7th, moving north-northwestward from the southwestern portion of the Gulf up the Rio Grande Valley and causing a mass of warm, moist air to move with more than normal velocity against the abrupt elevations of central Texas. Forecasts of precipitation, based on the movement of the disturbance, were made for south Texas on the 7th, 8th, and 9th.

In general, the conditions were unfavorable for extended forecasts for the benefit of harvesting and other interests, but on the 21st a forecast of fair weather in

Oklahoma for the following 60 hours was issued. Fair weather prevailed as forecast.—R. A. Dyke.

#### DENVER FORECAST DISTRICT.

An unusual number of LOWS advanced across this district from California or the southwestern portion of the Rocky Mountain Plateau, while, with one exception, all of the HIGHS that affected the weather conditions in the southern Rocky Mountain States approached from the coasts of Washington, Oregon, or northern California. Generally light, scattered showers occurred in portions of the district from the 1st to the 3d, the 11th to the 13th, on the 15th and 16th, the 17th and 18th, and the 23d and 24th. More general rains set in over Arizona on the night of the 29th-30th and extended northeastward to southern Utah and western Colorado by October 1, with excessive amounts in western Arizona.

Forecasts of frosts were issued for the higher elevations, as follows: On the 3d, for Utah and northern Arizona; 4th, southern Utah and northern Arizona; 8th, northern Arizona; 10th, Colorado, New Mexico, northern Arizona and Utah; 12th, Utah; 13th, Colorado and Utah; 20th, Colorado, northern New Mexico, northern Arizona, and southern Utah; 21st, northern New Mexico, northern Arizona and Utah; 29th, northern New Mexico, northern Arizona and Utah. Warnings of frosts at all elevations in eastern Colorado were issued on the 11th; in northern and western Utah on the 16th and 20th; the western valleys of Colorado on the 21st and 26th, and for the entire State of Colorado on the 29th. Forecasts of freezing temperatures in the mountains of Colorado were made on the 6th, 8th, 10th, 17th, and 26th, and at all elevations in extreme north-central Colorado on the 29th.

These warnings were justified by the occurrence of frosts, or by temperatures at which frosts might be expected in those sections, except on the 11th in northern northern New Mexico, Arizona, and Utah, on the 14th in Utah, and in eastern Colorado on the 12th. In the instance last named, when frost was expected at all elevations in the section specified, the area of high pressure advanced eastward more rapidly than was indicated at the time the warning was issued.

Light frost that was not forecast occurred at Flagstaff on the 8th and at Gallup on the 24th. A heavy frost, also without warning, was reported from Salt Lake City on the 20th, although the minimum temperature at that station was 42°.

In a special forecast that was issued for the Gunnison and Uncomphagre fruit valleys on the 20th, temperatures near freezing were predicted for the following night. The thermometer readings on the morning of the 21st ranged from 28° to 34°. A forecast of temperatures about freezing was also issued for the same valleys on the 29th, and the readings on the morning of the 30th ranged from 29° to 35°. The damage in both instances appears to have been confined to tender vegetation.—J. M. Sherier.

#### SAN FRANCISCO FORECAST DISTRICT.

The month opened with a period of unsettled and showery weather covering the first two days in California and the southern Plateau and the first eight days in western Washington. On the 18th a storm from the north Pacific passed inland far enough south to give the first general rain over the north Pacific States. There was a showery period over northern California on the 17th, 18th, and 19th and again on the 25th. Ample warnings were issued to fruit and raisin driers and no damage resulted. On the 30th a storm of the Sonora type caused heavy rains

in southern California, which probably did considerable damage to drying fruit and beans in that section. This storm moved rapidly north from the Gulf of California and rain had begun in the extreme south before warnings were issued.

A warm wave covered California from the 25th to the 29th and on the 26th at San Luis Obispo the record for high temperature in September was broken.

Frost warnings were issued on the 10th, 12th, 13th, 16th, and 20th in the Plateau region, and by the close of the month most of the stations in that section had either reported killing frosts or asked that frost warnings cease for the season.

Storm warnings were issued as follows: On the 20th, southwest warnings, mouth of Columbia River and Washington stations; 23d and 25th, southwest warnings at all Oregon and Washington stations; 27th, southwest warnings at the mouth of the Columbia River and Washington stations; 28th, northwest warnings at Eureka, Mendocino, and Fort Bragg. Advisory warnings were sent to all Washington and Oregon stations on the 23d; and small craft warnings were ordered at Eureka, Mendocino, and Fort Bragg on the 28th.

The following rain warnings were issued for the benefit of fruit driers: 1st, northern California; 3d, central coast and San Francisco Bay sections; 13th, San Francisco Bay section and Sacramento Valley; 17th, northern California, and 30th, California.—G. H. Willson.

#### RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

#### THE TEXAS FLOODS.

Torrential rains on September 9 and 10 caused general floods in the rivers of central and southern Texas. Over the drainage area of the San Antonio River, and thence northeastward through Williamson and Milan Counties into Bell County, the rain was excessive in amount and apparently unprecedented in rate of fall.

The rains were caused by a storm of tropical character that apparently moved inland, and to the north-northeastward, south of Tampico, Mexico, on September 7. Barometric evidence as to its movement subsequent to September 7 is lacking, but the times of beginning of heavy rains, as noted in the next paragraph, indicate the progression northeastward of an atmospheric disturbance the nature of which can not be definitely stated. At 8 a. m., September 8, a 24-hour rainfall of 6 inches was reported at Laredo, Webb County, Tex., on the Rio Grande. At 8 a. m., September 9, 4.05 inches was reported at Encinal, La Salle County, about 40 miles north of Laredo; and at 8 a. m., September 9, 5.70 inches at Hondo, Medina County, about 85 miles north of Encinal. These rains indicated a slow yet apparently steady northward movement of the excessive rain. The floods in the larger rivers were not severe except over the middle and lower Brazos drainage areas.

The following table shows the amount of rainfall from all available places of observation. Some of the reports in the San Antonio district were not official, and at 13 of the stations improvised gages, such as cans and barrels, were used. These latter were afterwards visited and the measurements carefully checked. This table was prepared by Mr. B. Bunnemeyer, in charge of the Weather Bureau office at Houston, Tex. The data for the outlying points near San Antonio are not included in Table I, but are shown in the table immediately following. Their positions may be identified by the corresponding numbers on the chart accompanying the San Antonio report. (See p. 495, this REVIEW.)

TABLE 1.—Rainfall reported September 7 to 11, 1921, arranged by drainage basins.

#### 1. RIO GRANDE DRAINAGE.

Station.	County.	Sept. 7.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Total.
Brownsville.....	Cameron.....	1.07	0.68	1.18			2.93
Eagle Pass.....	Maverick.....		0.07	0.05			0.12
Fort Clark.....	Kinney.....		0.28				0.28
Laredo.....	Webb.....	0.20	6.00				6.20
Harlingen.....	Cameron.....	0.42	0.27	2.14			2.83
Mission.....	Hidalgo.....	0.42	0.12				0.54
Rio Grande.....	Starr.....		0.15				0.15
San Benito.....	Cameron.....	0.92	0.13	0.78			1.83

#### 2. NUECES DRAINAGE.

Big Wells.....	Dimmit.....		0.23	1.29	0.02		1.54
Dilley.....	Frio.....		T.	1.62	1.81		3.43
Encinal.....	La Salle.....		0.06	4.05			4.11
George West.....	Live Oak.....	0.22	2.45	5.55	0.10		8.32
Hondo.....	Medina.....		0.65	5.70			6.35
La Pryor.....	Zavalla.....		0.80	0.02		0.02	0.84
Mathis.....	San Patricio.....	1.53	1.81	0.24			3.58
Montell.....	Uvalde.....	0.08	0.59		T.	0.04	0.71
Pearsall.....	Frio.....	T.	1.35	1.47			2.82
Rossville.....	Atascosa.....	0.02	0.13	1.16		T.	1.31
Sabinal.....	Uvalde.....	0.11	0.19	1.36			1.66
Whitsett.....	Live Oak.....		1.37	5.45			6.82

#### 3. SAN ANTONIO DRAINAGE.

Boerne.....	Kendall.....		0.23	6.45	0.04		6.72
Goliad.....	Goliad.....	0.56	0.49	2.20	0.03	0.36	3.64
Karnes City.....	Karnes.....		0.44	4.51			4.95
Runge.....	do.....		0.84	2.65			3.49
San Antonio.....	Bexar.....		0.54	6.84	T.		7.38

#### 4. GUADALUPE DRAINAGE.

Blanco.....	Blanco.....	0.18	0.15	1.72	5.80		7.85
Cuero.....	De Witt.....	0.22	1.37	0.46			2.05
Gonzales.....	Gonzales.....		0.12	1.63	1.24		2.99
Kerrville.....	Kerr.....	0.02	0.01	0.26	2.87	0.04	3.20
Luling.....	Caldwell.....		0.08	1.50	0.90		2.48
New Braunfels.....	Comal.....		0.18	9.38			9.56
San Marcos.....	Hays.....		2.00	8.00	1.50		11.50
Victoria.....	Victoria.....	0.75	0.65	1.02			2.42

#### 5. COLORADO DRAINAGE.

Austin.....	Travis.....	0.15	0.05	15.00	4.03	T.	19.23
Columbus.....	Colorado.....		0.14	2.00	0.30		2.44
Fairland.....	Burnett.....		0.05	3.40	5.30	T.	8.75
La Grange.....	Fayette.....	0.02	0.49	0.59	0.09		1.19
Llano.....	Llano.....		0.14	1.65			1.79
Marble Falls.....	Burnett.....	T.	0.57	5.50	11.00		17.07
Morris Ranch.....	Gillespie.....		0.02	1.24	0.24	0.01	1.51
Pierce.....	Wharton.....	0.92	3.85	T.	0.06		4.83
Smithville.....	Bastrop.....	0.58	0.28	1.16	1.36		3.38

#### 6. BRAZOS DRAINAGE.

Brazoria.....	Brazoria.....	0.83	0.88	0.96	0.13	0.34	3.14
Brenham.....	Washington.....	T.	0.01	2.14	0.28		2.38
Cameron.....	Milam.....	0.30	0.77	0.85	12.45		14.37
College Station.....	Brazos.....	T.	0.22	1.12	0.07		1.41
Copperas Cove.....	Coryell.....		1.07	2.85			3.92
Gatesville.....	do.....			1.00			1.00
Georgetown.....	Williamson.....	T.	0.06	0.70	13.00	1.43	15.19
Hamilton.....	Hamilton.....						0.00
Hempstead.....	Waller.....		0.50	0.77	0.06	0.00	1.33
Lampasas.....	Lampasas.....	1.50		0.03	1.10	0.70	3.23
Navasota.....	Grimes.....		0.55		0.53		1.08
Rosenberg.....	Fort Bend.....	0.40	2.00	1.22			3.62
Sealy.....	Austin.....	0.05	0.50	0.93			1.48
Somerville.....	Burleson.....			0.30	0.50		0.80
Sugarland.....	Fort Bend.....	0.25	1.95	0.18	0.27		2.65
Taylor.....	Williamson.....	0.04	0.28	16.11	7.87	0.18	24.48
Temple.....	Bell.....	0.04		0.35	9.00	2.55	11.94
Valley Junction.....	Robertson.....			0.25	2.00	0.32	2.57

#### 7. COAST DRAINAGE.

Alice.....	Jim Wells.....		1.80	1.25	0.02		3.07
Alvin.....	Brazoria.....	2.60	4.90	0.08	3.86		10.84
Angleton.....	do.....	0.49	1.12	0.13	0.06	0.06	1.88
Austwell.....	Refugio.....	0.96	1.76	0.18			2.90
Beeville.....	Bee.....	0.28	2.20	3.40	0.60		6.48
Corpus Christi.....	Nueces.....	0.42	0.84	1.45	T.		2.71
Danewang.....	Wharton.....		2.95	1.50			4.45
Edna.....	Jackson.....	0.47	2.63	0.70			3.80
Falfurrias.....	Brooks.....	0.09	0.98	T.			1.07
Hallettsville.....	Lavaca.....	0.11	0.20	0.75	0.02		1.11
La Parra.....	Kenedy.....	0.65	0.80	1.15			2.60
Matagorda.....	Matagorda.....	1.90	2.00	1.01	0.42		5.33
Ricardo.....	Kleberg.....	0.38	0.72	0.05			1.15
Santa Gertrudis.....	do.....	1.30	1.12	1.27			3.69
Woodboro.....	Refugio.....	0.97	0.98	1.72	0.05	0.25	3.97
Yoakum.....	Lavaca.....	0.25	0.24	0.74	0.11		1.34

TABLE 2.—Total rainfall, San Antonio and vicinity, September 8-10, inclusive, 1921. (See fig. 1, p. 495, this REVIEW.)

	Inches.		Inches.
No. 1.....	15.00	No. 7.....	13.00
No. 2.....	17.50	No. 8.....	13.18
No. 3.....	20.00	No. 9.....	12.00 to 15.00
No. 4.....	18.00	No. 10.....	8.55
No. 5.....	21.00	No. 11.....	9.50
No. 6.....	15.00	No. 12.....	6.84

There were standard rain-gages at Nos. 7, 8, 10, 11 and 12, and improvised gages at Nos. 1, 2, 3, 4, 5, 6, and 9. The figures for station No. 5 are not considered to be reliable, although there was a standard rain-gage.

The reader is referred for detailed reports of the Texas floods to the articles by Messrs. Bunnenmeyer, Jarboe, and McAuliffe, pages 491-497, this REVIEW.

## OTHER FLOODS.

There were several rises during the first half of the month in the interior rivers of Indiana and Missouri, but they were inconsequential, although as a whole justifying the warnings that were issued. The value of warnings of minor rises, even though high stages are not expected, is shown by the following extract from a report by Mr. M. W. Hayes, Meteorologist, in charge of the Weather Bureau office at St. Louis, Mo.:

At 7 a. m., September 5, the stage of the Mississippi at St. Louis was 4.8 feet. After the receipt of the 7 a. m. reports from upstream a rise of 6 feet, to occur by noon of the 6th, was forecast. The 5th was a holiday, and every effort was made to give the forecast the widest possible dissemination by telephone, as well as through the afternoon newspapers. The efforts seemed to have been successful, as the river banks were cleared of all property likely to be damaged or destroyed by water, the wharf-boats were pulled in, and engineering work at and below St. Louis was put in a condition to meet the rise. At 12 noon, September 6, the stage was 10.8 feet.

## EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS: SEPTEMBER, 1921.

By J. WARREN SMITH, Meteorologist.

Warm weather for the season was the rule throughout September in all sections of the country, except the far Northwest and parts of the West, and no extensive frost damage was experienced. Freezing temperatures were frequent in the far Northwest, but the cool waves dissipated rapidly in their eastward and southward progress, and freezing weather was confined to the northern Rocky Mountain and northern Plateau districts, the northwestern Great Plains, and in a few localities of the interior of the Northeast. There was some damage by low temperatures in the Northwest, where it was too cool for the proper development of late crops, but the staple crops had largely matured and were not harmed to any great extent.

Farm work was considerably interrupted by rain in the interior Northern States, and during part of the month in some southwestern localities; otherwise the weather was favorable for outdoor operations, and farm work made generally good progress.

Corn matured rapidly with warm weather and considerable sunshine. Most of it was beyond frost danger in Ohio, northern Illinois, Iowa, Missouri, and Nebraska by the middle of the month. Considerable harm was done, however, by molding, sprouting, and rotting in portions of the upper Mississippi Valley by continued wet weather and high temperatures during the latter part of the month, and drying weather was badly needed in all of the central Mississippi Valley States. Late corn

## Flood stages during the month of September, 1921.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
Mississippi drainage, Des Moines.....	Ottumwa, Iowa.....	Feet. 10	17	18	Feet. 11.4	17
West Gulf:						
Brazos.....	Valley Junction, Tex.	44	11	13	58.2	12
	Washington, Tex.....	45	13	17	50.0	14
	Hempstead, Tex.....	40	16	16	40.2	16
	Austin, Tex.....	18	10	10	19.0	10
Colorado.....	Columbus, Tex.....	28	12	13	33.8	13
	Smithville, Tex.....	24	11	11	26.0	11
Guadalupe.....	Gonzales.....	22	11	13	31.4	11
	Victoria, Tex.....	16	14	16	20.5	16
Rio Grande.....	Rio Grande City, Tex.	15	10	10	18.0	10

## MEAN LAKE LEVELS DURING SEPTEMBER, 1921.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., October 5, 1921.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes. <sup>1</sup>			
	Superior.	Michigan and Huron.	Erie.	Ontario.
	Feet.	Feet.	Feet.	Feet.
Above mean sea level at New York.....	602.67	580.04	572.17	245.43
Above or below—				
Mean stage of August, 1921.....	-0.10	-0.14	-0.32	-0.50
Mean stage of September, 1920.....	-0.14	-0.83	-0.22	-0.04
Average stage for September, last 10 years.....	-0.05	-0.68	-0.27	-0.74
Highest recorded September stage.....	-1.41	-3.39	-1.77	-2.18
Lowest recorded September stage.....	+1.18	+0.38	+0.89	+1.43
Average relation of the September level to:				
August level.....		-0.20	-0.20	-0.30
October level.....		+0.20	+0.30	+0.30

<sup>1</sup> Lake St. Clair's level: In September, 574.99 feet.

needed rain in the Southern States, but the harvest of the early crop made good progress.

There was little or no improvement in cotton during the month. The weather was mostly warm and dry, although considerable damage resulted from excessive rains in central and southwestern Texas at the close of the first decade. The continued hot, dry weather was unfavorable in the eastern portions of the belt where plants lost vigor and shed badly in most places. Very little or no top crop was reported from any section of the belt. Cotton bolls opened very rapidly, and picking and ginning made good progress. At the close of the month picking was well advanced in Texas, while the crop had practically all been gathered in the southern half of Georgia, most sections of Florida, and in many localities in southern Alabama. Weevil activity continued marked, with a further spread toward the north-eastern limits of the belt.

The weather was favorable for harvesting late grains, and for thrashing, in the late northwestern districts. During the first half of the month the soil was mostly in good condition for preparation for seeding throughout the principal grain-growing States. Seeding made rather slow progress, however, in the interior valleys the latter part of the month, on account of frequent rains and wet soil, but rapid advance was made in the Great Plains States; this work was begun later than the average in most sections.

Truck crops were unfavorably affected by continued dry weather in the Southeast, especially in Florida, but conditions were more favorable in the central valley States, and truck made good progress on the Pacific coast.

Pastures continued in good condition in most interior States, but there was a lack of moisture in most of the South, while rain was needed in some central Rocky Mountain areas. Range grass cured well in most west-

ern grazing sections and, at the close of the month, stock were being moved from summer ranges in parts of the Rocky Mountain States.

The weather was favorable for drying fruit in California, but the continued dry weather in Florida unfavorably affected citrus fruit in that State where much dropping was reported. Citrus continued in excellent condition in California.

## CLIMATOLOGICAL TABLES.\*

## CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, September, 1921.

Section.	Temperature.							Precipitation.				
	Section average.	Departure from the normal.	Monthly extremes.				Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.			Station.	Amount.	Station.	Amount.
Alabama.....	81.2	+6.2	Madison.....	102	5	Valley Head.....	53	30	2.73	-0.76	Tusculum.....	6.49
Arizona.....	73.7	+0.1	2 stations.....	112	12†	Fort Valley.....	31	19	0.73	-0.37	Soldier Camp.....	5.09
Arkansas.....	79.6	+6.0	2 stations.....	104	2†	Gravette.....	35	30	3.38	+0.03	Arkansas City.....	6.96
California.....	67.3	-1.2	Greenland Ranch.....	116	13	Fordyce Dam.....	26	15	0.41	-0.08	Nellie.....	4.40
Colorado.....	58.3	+1.1	2 stations.....	100	14†	2 stations.....	3	21†	0.53	-0.97	Cheyenne Wells.....	3.81
Florida.....	81.6	+2.7	Orlando.....	103	7	Glen St. Mary.....	56	16	2.25	-4.53	Punta Gorda.....	8.20
Georgia.....	81.2	+6.2	3 stations.....	104	1†	Blue Ridge.....	57	22†	2.23	-1.44	Cornelia.....	6.22
Hawaii.....	74.3	-0.3	Mahukona.....	94	15	3 stations.....	52	2†	3.78	-1.92	Eke, Maui.....	18.50
Idaho.....	53.0	-3.9	Glenns Ferry.....	98	6	Stanley.....	10	12†	0.85	-0.30	Oxford R. S.....	4.32
Illinois.....	71.6	+4.6	Mount Carmel.....	98	16	4 stations.....	40	26	6.62	+3.10	Henry.....	10.07
Indiana.....	71.4	+4.7	Wheatfield.....	98	28	4 stations.....	38	25	5.58	+2.58	Veederburg.....	12.20
Iowa.....	67.3	-3.9	Mount Pleasant.....	99	4	2 stations.....	31	30	6.72	+3.36	Olin.....	11.95
Kansas.....	73.7	+4.6	Salina.....	107	3	2 stations.....	30	30	3.48	+0.58	Paola.....	10.07
Kentucky.....	75.5	+5.5	2 stations.....	99	4	Owensboro.....	45	30	5.37	+2.61	Eubank.....	9.53
Louisiana.....	81.5	+4.2	2 stations.....	102	11†	Calhoun.....	52	30	3.14	-0.74	Covington.....	6.78
Maryland-Delaware.....	72.6	+5.3	2 stations.....	99	2	Oakland, Md.....	37	26	3.33	+0.23	Friensville, Md.....	7.63
Michigan.....	64.9	+5.0	Adrain.....	95	1	Deer Park.....	21	16	3.81	+0.73	Port Austin.....	7.50
Minnesota.....	60.5	+2.8	Beardsley.....	99	1	Itasca State Park.....	27	29	4.32	+1.56	Canby.....	8.32
Mississippi.....	81.5	+5.9	2 stations.....	103	13	2 stations.....	46	30	3.14	-0.33	Greenville.....	6.66
Missouri.....	73.4	+4.7	Caruthersville.....	104	4†	Steffenville.....	34	30	7.03	+3.15	Avalon.....	14.95
Montana.....	51.1	-3.9	Ballantine.....	98	1	Wheaton.....	10	11	1.22	-0.28	Outlook.....	3.91
Nebraska.....	66.4	+2.7	2 stations.....	105	3	Nemsel.....	23	30	2.32	+0.19	Nebraska City.....	10.21
Nevada.....	61.9	-0.4	Logandale.....	105	4	San Jacinto.....	16	16	0.24	-0.22	Searchlight.....	2.02
New England.....	63.1	+3.3	Somerset, Vt.....	96	1†	2 stations.....	25	19†	2.42	-1.12	Waterbury, Conn.....	7.50
New Jersey.....	70.2	+4.5	Bridgeton.....	99	2	Charlotteburg.....	36	27	2.35	-1.26	Sussex.....	5.04
New Mexico.....	66.1	+1.9	2 stations.....	101	5†	Senorito (near).....	21	21	0.87	-0.65	Portales.....	6.44
New York.....	65.5	+4.6	2 stations.....	97	2†	Indian Lake.....	29	27	2.55	-0.79	Townsend.....	5.62
North Carolina.....	76.4	+6.6	Tarboro.....	104	2	Banners Elk.....	46	24	2.84	-1.03	Rock House.....	7.54
North Dakota.....	57.0	+0.6	Hettinger.....	101	1	Hettinger.....	25	30	3.30	+1.66	Pembina.....	6.83
Ohio.....	70.1	+4.6	2 stations.....	98	1	3 stations.....	38	26	4.29	+1.67	Amesville.....	8.74
Oklahoma.....	79.0	+5.0	Oakwood.....	106	4	3 stations.....	32	30	2.92	+0.01	Reno Junction.....	7.83
Oregon.....	56.3	-2.3	Blitzen.....	92	1	Lapine.....	5	13	1.35	-0.01	Cascade Locks.....	5.12
Pennsylvania.....	68.9	+5.1	4 stations.....	98	2	Bradys Bend.....	31	24	4.68	+1.35	Clearfield.....	11.48
South Carolina.....	80.0	+5.8	Florence No. 1.....	104	4	Darlington.....	57	24	3.42	-0.51	Clemson College.....	7.54
South Dakota.....	61.3	+1.0	Hopewell.....	104	1	4 stations.....	26	11	3.01	+2.07	La Delle.....	10.06
Tennessee.....	77.7	+6.6	Clarksville.....	102	5	Kenton.....	50	30	4.34	+1.33	Johnsonville.....	11.31
Texas.....	81.1	+4.0	Big Spring.....	107	10	Dalhart.....	35	30	4.02	+1.20	Taylor.....	25.87
Utah.....	59.2	-0.8	St. George.....	99	27	2 stations.....	18	17†	0.47	-0.69	New Harmony.....	2.06
Virginia.....	74.1	+5.9	Randolph.....	104	2	3 stations.....	46	22†	2.80	-0.58	Fredericksburg.....	5.61
Washington.....	55.1	-2.9	Wheeler.....	91	27	2 stations.....	19	13	2.16	+0.47	Paradise Inn.....	16.27
West Virginia.....	70.9	+5.1	2 stations.....	97	1†	Bayard.....	39	26	4.76	+1.99	Bruceton Mills.....	9.07
Wisconsin.....	63.4	+3.9	Richland Center.....	96	3	Long Lake.....	27	26	4.92	+1.39	Watertown.....	11.02
Wyoming.....	54.0	-0.7	3 stations.....	98	2†	South Pass City.....	10	29	0.51	-0.77	Dutch Joe.....	1.44

\*For description of tables and charts, see REVIEW, January, 1921, p. 41.

†Other dates also.

TABLE 1.—Climatological data for Weather Bureau Stations, September, 1921.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Precipitation.				Wind.											
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + min. - 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature dew-point.	Mean relative humidity.	Total.	Days with .01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.		Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow sleet and ice on ground at end of month.		
																							Miles per hour.	Direction.							Date.	
New England.	Ft.	Ft.	Ft.	In.	In.	In.	° F. 65.0	° F. + 4.5	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	% 78	In. 1.93	In. - 1.2	Miles 7.262	s.	38	s.	22	11	12	7	4.7	0.0	0.0	
Eastport.....	76	67	85	29.90	29.98	- .05	59.2	+ 4.0	88	3	68	44	19	51	29	54	51	81	2.36	- 0.6	11	7,262	s.	38	s.	22	11	12	7	4.7	0.0	0.0
Greenville, Me.....	1,070	82	117	29.93	29.99	- .03	63.3	+ 3.7	91	3	72	44	21	55	26	57	53	73	1.64	- 1.6	10	6,073	s.	40	se.	21	19	5	6	3.3	0.0	0.0
Potterland, Me.....	288	70	79	29.92	30.02	- .04	63.3	+ 4.2	92	2	76	36	27	50	40	57	53	73	2.40	- 0.8	10	3,072	nw.	22	s.	17	20	4	6	3.5	0.0	0.0
Concord.....	404	11	48	29.96	29.99	- .07	62.7	+ 3.8	90	2	74	38	27	52	34	54	51	80	2.54	- 0.8	9	7,880	s.	48	sw.	30	11	9	10	5.0	0.0	0.0
Burlington.....	576	12	60	29.98	30.02	- .04	59.0	+ 4.4	88	3	73	30	27	45	43	54	51	80	1.70	- 1.0	11	5,058	s.	38	sw.	30	9	10	11	5.7	0.0	0.0
Northfield.....	125	115	188	29.98	30.02	- .05	68.5	+ 5.8	93	3	77	53	27	60	27	61	57	71	1.22	- 1.0	11	6,436	sw.	31	w.	18	15	9	6	4.2	0.0	0.0
Nantucket.....	12	14	90	30.02	30.03	- .05	66.7	+ 3.9	87	3	73	49	21	60	19	62	60	84	1.22	- 1.5	11	9,853	sw.	43	sw.	25	12	13	5	4.8	0.0	0.0
Block Island.....	26	11	46	30.00	30.03	- .05	67.0	+ 2.9	83	3	72	54	27	62	17	63	61	85	0.80	- 2.2	11	9,502	sw.	42	sw.	22	16	6	8	4.2	0.0	0.0
Providence.....	160	215	251	29.93	30.02	- .05	68.0	+ 4.8	92	3	77	48	27	59	26	61	57	74	1.33	- 1.8	8	7,476	nw.	39	nw.	18	13	12	5	4.2	0.0	0.0
Hartford.....	159	122	140	29.85	30.02	- .05	68.8	+ 7.1	95	2	79	44	27	59	28	61	57	74	3.21	- 0.3	8	8,816	s.	40	sw.	30	10	11	9	5.3	0.0	0.0
New Haven.....	106	74	153	29.82	30.03	- .04	68.8	+ 4.9	92	3	78	48	27	60	24	62	59	76	2.77	- 1.0	11	5,871	sw.	38	sw.	30	14	11	5	4.0	0.0	0.0
Middle Atlantic States.							72.2	+ 3.7										76	2.41	- 1.0									4.9			
Albany.....	97	102	115	29.91	30.01	- .06	67.7	+ 5.4	94	2	78	42	27	58	30	60	51	74	1.44	- 1.7	9	5,184	s.	33	s.	25	18	7	5	3.5	0.0	0.0
Binghamton.....	871	10	84	29.10	30.02	- .05	67.0	+ 4.0	93	2	78	42	27	56	34	63	59	72	3.20	+ 0.4	10	3,491	ne.	24	sw.	30	9	9	12	5.4	0.0	0.0
New York.....	314	414	454	29.70	30.03	- .05	71.0	+ 7.5	91	3	78	56	19	64	25	63	59	72	2.96	+ 0.6	10	10,223	s.	56	nw.	3	9	12	9	5.3	0.0	0.0
Harrisburg.....	374	94	104	29.65	30.04	- .04	70.8	+ 5.9	94	1	79	53	24	62	26	63	59	71	2.73	- 0.1	12	3,567	w.	32	sw.	30	8	14	8	5.4	0.0	0.0
Philadelphia.....	117	123	190	29.92	30.05	- .03	72.8	+ 5.4	92	3	80	58	27	65	26	66	64	78	2.21	- 1.2	8	5,845	s.	38	s.	30	9	11	10	5.4	0.0	0.0
Reading.....	325	81	98	29.70	30.04	- .04	71.3	+ 5.9	95	2	81	52	27	62	29	63	59	73	3.70	+ 0.5	9	2,351	se.	28	nw.	30	13	8	9	5.2	0.0	0.0
Seranton.....	805	111	119	29.18	30.03	- .04	68.1	+ 5.9	90	1	78	45	27	58	31	60	57	73	4.38	+ 1.0	9	4,194	sw.	36	sw.	30	10	13	7	4.9	0.0	0.0
Atlantic City.....	52	37	48	29.98	30.03	- .04	71.6	+ 4.0	93	3	77	56	19	66	24	67	64	81	1.51	- 1.5	9	4,968	s.	27	s.	21	14	8	8	4.6	0.0	0.0
Cape May.....	18	13	49	30.05	30.07	- .00	72.9	+ 3.9	93	3	79	55	24	66	20	67	65	82	0.80	- 2.2	7	5,587	s.	34	nw.	30	11	12	7	4.8	0.0	0.0
Sandy Hook.....	22	10	55	30.01	30.03	- .03	71.4	+ 5.9	93	3	77	60	19	66	23	65	62	77	1.47	- 1.9	8	9,378	s.	52	s.	30	11	9	10	5.1	0.0	0.0
Trenton.....	190	159	183	29.83	30.03	- .06	70.6	+ 5.9	93	2	80	52	27	62	29	63	59	73	1.69	- 1.9	7	6,287	s.	58	s.	30	8	10	12	6.0	0.0	0.0
Baltimore.....	123	100	113	29.90	30.02	- .06	74.5	+ 5.9	96	2	82	60	30	67	24	66	62	70	3.19	- 0.7	7	3,704	s.	24	sw.	30	8	13	9	5.4	0.0	0.0
Washington.....	112	62	85	29.92	30.03	- .05	74.4	+ 6.3	95	2	84	55	24	65	28	66	62	74	3.29	+ 0.3	9	3,399	sw.	33	nw.	30	11	12	7	4.8	0.0	0.0
Lynchburg.....	681	158	188	29.92	30.05	- .03	75.5	+ 7.1	96	2	86	54	30	65	26	66	63	74	1.71	- 1.9	6	6,199	e.	34	w.	4	11	14	5	4.5	0.0	0.0
Norfolk.....	91	170	205	29.96	30.05	- .01	77.8	+ 6.1	96	2	86	63	30	70	24	70	67	79	2.43	- 1.6	9	6,909	s.	29	s.	30	12	15	3	4.2	0.0	0.0
Richmond.....	144	11	52	29.90	30.04	- .03	76.8	+ 6.0	98	2	87	57	20	66	29	68	64	74	0.95	- 2.5	10	4,493	ne.	36	nw.	30	10	11	9	5.1	0.0	0.0
Weytheville.....	2,304	40	56	27.75	30.06	- .01	70.0	+ 6.4	97	16	80	46	30	60	31	63	62	85	2.34	- 1.0	16	2,909	w.	24	w.	30	12	14	4	4.1	0.0	0.0
South Atlantic States.							79.4	+ 6.3										79	2.72	- 1.9										4.1		
Asheville.....	2,255	70	84	27.78	30.07	- .00	71.7	+ 6.7	89	17	82	50	30	61	30	65	63	85	1.57	- 1.5	12	3,343	nw.	27	n.	21	6	19	5	5.3	0.0	0.0
Charlotte.....	779	55	62	29.23	30.04	- .03	79.2	+ 8.5	96	4	89	60	27	69	26	69	66	73	2.55	- 0.7	8	2,135	n.	20	w.	25	15	8	7	4.6	0.0	0.0
Hatteras.....	11	12	50	30.03	30.04	- .02	77.2	+ 2.5	86	5	82	67	4	72	17	73	71	82	5.03	- 0.3	10	7,253	n.	50	nw.	4	11	14	5	4.4	0.0	0.0
Manteo.....	12	5	42	29.98	30.03	- .04	78.5	+ 7.9	97	2	89	56	30	68	29	70	67	76	3.01	- 0.3	13	4,120	sw.	33	n.	4	12	14	4	4.2	0.0	0.0
Raleigh.....	376	103	110	29.65	30.03	- .04	78.5	+ 7.9	97	2	89	56	30	68	29	70	67	76	3.01	- 0.3	13	4,120	sw.	33	n.	4	12	14	4	4.2	0.0	0.0
Wilmington.....	78	81	91	29.97	30.05	- .00	79.2	+ 6.1	95	5	88	67	20	71	25	72	70	83	1.86	- 3.4	8	3,770	sw.	24	n.	5	15	14	1	3.7	0.0	0.0
Charleston.....	48	11	92	30.00	30.05	- .01	81.9	+ 5.7	96	6	89	68	28	74	20	74	72	79	5.19	- 0.3	6	5,706	s.	34	ne.	8	20	9	1	2.8	0.0	0.0
Columbia, S. C.....	351	41	57	29.68	30.06	+ .01	80.8	+ 7.1	98	4	91	64	24	71	27	71	68	74	1.83	- 1.6	9	3,497	s.	31	sw.	1	12	13	5	4.4	0.0	0.0
Due West, S. C.....	711	10	55	29.33	30.08	- .08	79.4	+ 6.7	97	3	90	63	23	69	27	73	70	76	6.49	- 1.4	8	4,327	ne.	46	nw.	21	11	14	5	4.9	0.0	0.0
Greenville, S. C.....	1,089	113	122	28.97	30.04	- .04	78.2	+ 6.7	105	4	92	65	27	68	26	69	66	75	2.33	- 1.4	8	3,734	s.	23	nw.	21	9	17	4	4.0	0.0	0.0
Augusta.....	180	62	77	29.85	30.04	- .01	81.6	+ 7.2	100	4	92	62	24	71	29	73	70	76	2.33	- 1.4	8	3,734	s.	23	nw.	21	9	17	4	4.0	0.0	0.0
Savannah.....	65	150	194	29.98	30.06	+ .03	82.0	+ 6.6	97	6	91	69	28	73	22	74	72	80	2.07	- 3.5	5	5,821	ne.	27	w.	8	19	11	0	3.0	0.0	0.0
Jacksonville.....	43	209	245	30.00	30.05	+ .05	81.6	+ 4.3	95	5	89	70	14	74	20	74	72	83	1.73	- 6.3	6	6,697	ne.	35	sw.	8	17	13	0	3.1	0.0	0.0
Florida Peninsula.							81.9	+ 0.7										76	3.28	- 4.6										4.8		
Key West.....	22	10	64	29.96	29.98	+ .04	82.2	- 0.3	90	10	87	72	2	77	15	76	73	76	5.45	- 1.3	20	6,513	e.	33	se	1	10	15	5	4.8	0.0	0.0
Miami.....	25	71	79	29.99	30.02	- .03	80.9	- 0.6	87	5	86	72	22	76	15	75	73	75	2.81	- 6.8	12	6,035	e.	22	e.	16	13	9	8	4.7	0.0	0.0
Sand Key.....	23	39	72	29.97	30.00	+ .06	81.0	- 0.6	89	10	84	71	17	78	13	76	74	77	3.77	- 1.1	11	9,332	e.	44	se.	1	8	16	6	5.1	0.0	0.0
Tampa.....	35	79	92	29.99	30.02	+ .05	82.7	+																								

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TABLE 1.—Climatological data from Weather Bureau Stations, September, 1921—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.					
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. +2.	Departure from normal.	Maximum.	Date.	Mean minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with .01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.											
																							Miles per hour.							Direction.	Date.			
Northern Slope.																																		
Billings.	3,140	5					56.0		95	1	73	22	11	40	51			0.46		2														
Havre.	2,505	11	44	27.31	29.94	-.00	52.6	-.50	80	2	65	28	11	40	44	36	61	1.50	+0.5	10	5,759	sw.	40	w.	26	5	18	7		0.0	0.0			
Helena.	4,110	87	112	25.79	29.98	+.01	50.8	-.54	78	1	61	28	11	41	36	41	31	54	1.09	0.0	8	6,474	sw.	42	sw.	26	7	10	13	6.1	1.5	0.0		
Kalispell.	2,973	48	56	26.92	29.97	+.01	48.8	-.51	69	17	60	27	11	38	35	40	32	57	0.79	-0.5	8	4,668	nw.	34	sw.	26	5	13	12	6.0	T.	0.0		
Miles City.	2,371	26	48																															
Rapid City.	3,259	50	58	26.57	29.94	-.02	59.5	+.04	93	1	73	29	11	46	49	48	36	46	0.95	-0.3	8	6,249	w.	44	nw.	28	11	14	5	4.5	0.0	0.0		
Cheyenne.	6,068	84	101	24.03	29.89	-.07	58.4	+.12	82	23	73	32	29	44	43	44	32	43	0.02	-0.9	2	9,614	w.	58	sw.	20	21	7	2	2.5	0.0	0.0		
Lander.	5,372	60	68	24.64	29.94	-.02	55.1	-.01	86	1	72	28	11	38	48	42	31	46	0.13	-0.9	4	4,153	w.	42	sw.	18	19	11	0	3.1	T.	0.0		
Sheridan.	3,790	10	47	26.08	29.96		55.0		92	1	70	21	11	40	54	43	32	54	0.51	0.0	8	4,234	nw.	32	n.	28	16	6	8	4.3	0.0	0.0		
Yellowstone Park.	6,200	11	48	23.89	29.97	-.00	46.6	-.68	73	1	58	23	29	35	38	37	29	54	0.84	-0.2	7	6,660	s.	39	sw.	22	8	14	8	5.3	0.1	0.0		
North Platte.	2,821	11	51	27.06	29.96	-.01	65.0	+.18	95	23	80	33	30	50	50	55	49	68	1.00	-0.5	6	4,955	se.	34	n.	28	20	5	5	3.2	0.0	0.0		
Middle Slope.																																		
Denver.	5,292	106	113	24.73	29.90	-.06	63.9	+.12	91	14	79	37	30	49	43	49	38	46	0.02	-0.9	1	5,248	s.	44	nw.	20	22	7	1	2.3	0.0	0.0		
Pueblo.	4,655	80	86	25.27	29.88	-.08	66.7	+.23	95	14	83	33	30	51	45	51	39	45	0.25	-0.4	1	4,573	s. nw.	36	nw.	20	19	10	1	2.9	0.0	0.0		
Concordia.	1,392	50	58	28.46	29.90	-.09	73.8	+.57	102	3	86	43	30	61	45	61	55	61	1.36	-1.2	7	6,924	s.	28	s.	9	14	11	5	4.0	0.0	0.0		
Dodge City.	2,509	11	51	27.36	29.91	+.07	73.0	+.48	98	2	86	39	30	60	45	61	55	64	1.53	-0.2	6	8,595	s.	37	sw.	8	22	7	1	2.0	0.0	0.0		
Wichita.	1,358	139	158	28.50	29.90	-.10	75.3	+.55	97	3	85	45	30	66	29	65	61	68	1.53	+.09	12	10,144	s.	42	nw.	7	13	12	5	6.7	0.0	0.0		
Altus.	1,410	5					80.3		103	4	92	45	30	68	33				1.67		6		s.									0.0	0.0	
Broken Arrow.	765	11	52				81.0		100	14	93	41	30	69	39				1.49		8		e.									0.0	0.0	
Muskogee.	652	4					78.0	+.59	98	4	88	44	30	68	31	68	64	71	3.79	+1.0	10	7,599	s.	31	n.	24	9	18	3	4.2	0.0	0.0		
Oklahoma City.	1,214	10	47	28.68	29.92	-.07	78.2	+.54											39	0.52	-2.0											0.0	0.0	
Southern Slope.																																		
Abilene.	1,738	10	52	28.15	29.91	-.05	81.0	+.68	98	4	92	48	30	70	30	67	61	61	0.94	-2.2	5	7,738	s.	30	se.	5	18	7	5	3.6	0.0	0.0		
Amarillo.	3,676	10	49	26.26	29.92	-.04	73.6	+.59	96	2	86	42	30	61	36	61	55	63	0.76	-1.6	6	8,530	s.	32	sw.	29	16	13	1	3.4	0.0	0.0		
Del Rio.	944	64	71	28.94	29.90	-.04	83.8	+.49	96	4	93	66	30	75	23				0.12	-2.4	3	8,194	se.	26	ne.	29	14	14	2	3.8	0.0	0.0		
Roswell.	3,566	75	85	26.34	29.87	-.05	74.2	+.39	97	9	88	45	30	60	38	59	50	54	0.26	-2.0	4	4,562	s.	42	nw.	23	13	13	4	4.2	0.0	0.0		
Southern Plateau.																																		
El Paso.	3,762	110	133	26.16	29.83	-.05	76.5	+.38	96	7	88	58	30	65	31	62	53	52	2.49	+1.0	8	5,641	w.	36	ne.	25	16	12	2	3.4	0.0	0.0		
Santa Fe.	7,013	57	66	23.31	29.85	-.08	63.5	+.29	83	27	76	40	30	51	32	49	39	48	0.18	-1.5	3	4,758	w.	24	s.	18	18	8	4	3.0	0.0	0.0		
Flagstaff.	6,908	10	59	23.42	29.88	-.01	57.7	+.22	81	26	73	36	4	42	40				0.83		2		sw.	30	sw.	18	24	5	1	1.0	0.0	0.0		
Phoenix.	1,108	76	81	28.66	29.78	-.03	82.6	+.12	105	25	98	60	21	67	40	54	54	43	0.33	-0.7	2	3,424	w.	20	w.	18	24	5	1	1.0	0.0	0.0		
Yuma.	141	9	64	29.62	29.76	-.02	83.8	-.01	109	25	99	62	18	68	41	67	58	51	3.65	+3.5	2	2,977	sw.	25	s.	27	27	1	2	1.1	0.0	0.0		
Independence.	3,957	9	41	25.92	29.88	+.02	69.4	+.03	92	28	85	45	17	54	41	49	26	23	0.01	-0.1	1	3,687	s.	30	s.	17	26	4	0	0.7	0.0	0.0		
Middle Plateau.																																		
Reno.	4,532	74	81	25.46	29.90	-.05	60.6	+.09	88	27	78	33	13	43	46	44	28	36	0.12	-0.2	1	4,758	w.	40	w.	1	24	5	1	1.3	0.0	0.0		
Tonopah.	6,090	12	20	24.08	29.89		64.8		84	26	76	43	18	53	27	47	28	30	0.25	-0.2	1	4,864	w.	25	se.	2	24	6	0	1.0	0.0	0.0		
Winnemucca.	4,344	18	56	25.61	29.96	+.03	57.4	-.31	86	27	76	26	30	39	53	43	30	39	0.01	-0.3	1	4,615	ne.	27	sw.	19	23	4	3	1.8	0.0	0.0		
Modena.	5,479	10	43	24.62	29.89	-.03	60.2	0.0	86	26	78	32	30	42	49	44	25	32	0.23	-0.9	2	8,023	sw.	50	sw.	2	27	2	1	0.8	0.0	0.0		
Salt Lake City.	4,360	163	203	25.61	29.93	-.02	62.6	-.25	86	22	74	40	30	51	35	48	35	40	0.44	-0.4	3	5,389	nw.	48	nw.	2	23	5	2	2.0	0.0	0.0		
Grand Junction.	4,602	60	68	25.36	29.89	-.06	67.6	+.12	91	14	82	40	30	53	40	50	36	37	0.04	-0.9	1	4,423	se.	32	s.	18	22	8	0	2.0	0.0	0.0		
Northern Plateau.																																		
Baker.	3,471	48	53	26.46	30.04	+.05	50.3	-.67	80	27	64	21	12	36	43	43	39	61	0.80	0.0	5	4,253	se.	25	sw.	19	15	7	8	4.3	0.0	0.0		
Boise.	2,739	78	86	27.15	30.00	+.03	57.6	-.43	83	17	71	34	12	44	43	48	38	52	0.61	+0.2	3	3,362	se.	27	w.	19	19	7	4	3.1	0.0	0.0		
Lewiston.	757	40	48	29.19	30.00	+.02	58.6	-.49	88	17	72	33	13	46	46				0.79	+0.1	8	2,412	e.	24	nw.	28	13	4	13	5.4	0.0	0.0		
Pocatello.	4,477	60	68	25.47	29.95	-.01	56.2	-.45	85	1	70	29	29	42	43	43	31	43	0.56	-0.3	4	5,615	se.	36	sw.	2	18	7	8	3.7	0.0	0.0		
Spokane.	1,929	101	110	27.96	30.01	+.03	54.6	-.42	80	17	65	33	29	44	33	46	36	53	0.44	-0.6	7	5,564	sw.	39	sw.	27	6	10	14	6.1	0.0	0.0		
Walla Walla.	991	57	65	28.94	30.01	+.01	59.6	-.58	84	17	70	36	12	49	37	49	39	50	0.79	-0.1	1	3,392	s.	22	w.	27	9	12	9	5.0	0.0	0.0		
North Pacific Coast Region.																																		
North Head.	211	8	56	29.82	30.04	+.01	55.9	-.03	65	10	60	48	30	52	13	54	52	80	3.78	+1.9	15	9,576	n.	60	s	20	13	8	9	4.8	0.0	0.0		
Port Angeles.	29	11	53	30.04	30.07		53.9		72	10	62	38	30	46	30				1.99	+0.2	1	3,701	s.	30	sw.	27	9	10	12	5.3	0.0	0.0		
Seattle.	125	215	250	29.93	30.06	+.05	57.0	-.09	70	13	64	43	29	50	24	52	48	76	1.84	-0.1	14	5,944	s.	47	s.	27	5	10	15	6.5	0.0	0.0		
Tacoma.	86	213	120	29.85	30.07	+.06	56.3	-.13	72	15	64	39	29	48	29				1.59	-0.9	13	4,366	sw.	33	sw.	26	3	16	11	6.7	0.0	0.0		
Tatoosh Island.	213	7	57	29.92	30.02	+.01	54.1	-.1	62	11	58	46	30	50	13	52	50	89	7.76	+1.6	16	8,674	s.	76										

TABLE 2.—Data furnish by the Canadian Meteorological Service, September, 1921.

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Depart- ure from normal.	Mean max.+ mean min.+2.	Depart- ure from normal.	Mean maxi- mum.	Mean mini- mum.	Highest.	Lowest.	Total.	Depart- ure from normal.	Total snowfall.
		Fect.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	In.	In.	In.
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.93	29.98	-.03	58.2	+1.7	67.4	49.0	85	40	1.92	-1.36	0.0
Halifax, N. S.	88												
Yarmouth, N. S.	65	29.92	29.99	-.06	57.7	+1.6	65.2	50.2	77	38	2.32	-1.13	0.0
Charlottetown, P. E. I.	38	29.90	29.94	-.07	59.2	+1.9	60.9	51.4	85	37	4.50	+1.10	0.0
Chatham, N. B.	28	29.92	29.95	-.05	57.5	+2.1	67.6	47.4	90	32	2.61	-0.10	0.0
Father Point, Que.	20	29.87	29.89	-.09	50.8	+0.4	59.6	42.0	82	28	2.96	-0.27	0.0
Quebec, Que.	296	29.83	29.95	-.06	57.7	+2.6	66.6	48.9	85	37	5.22	+1.55	0.0
Montreal, Que.	187	29.74	29.94	-.10	61.9	+3.5	70.4	53.4	86	44	3.74	+0.44	0.0
Stonecliffe, Ont.	489	29.34	29.94	-.09	56.7	+1.0	73.3	40.1	92	14	1.76	-1.52	0.0
Ottawa, Ont.	236	29.69	29.95	-.09	62.9	+5.5	75.8	50.0	94	37	1.51	-1.18	0.0
Kingston, Ont.	285	29.66	29.96	-.08	65.7	+5.7	73.8	57.6	85	44	2.24	-0.56	0.0
Toronto, Ont.	379	29.57	29.96	-.10	67.7	+8.7	78.7	56.6	92	43	1.26	-1.99	0.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.54	29.84	-.14	53.6	+3.3	64.9	42.3	87	26	4.11	+1.34	0.0
Port Stanley, Ont.	592	29.37	30.00	-.06	65.4	+5.9	73.9	56.9	86	42	4.54	+1.81	0.0
Southampton, Ont.	656	29.24			64.5	+7.0	73.7	55.4	86	40	3.70	+0.76	0.0
Parry Sound, Ont.	688	29.22	29.90	-.13	64.0	+8.0	75.8	52.2	89	36	2.35	-1.32	0.0
Port Arthur, Ont.	644	29.16	29.87	-.11	57.5	+5.3	66.5	48.6	89	35	2.84	-0.64	0.0
Winnipeg, Man.	700	28.98	29.80	-.14	56.8	+4.3	65.8	47.8	91	36	3.63	+1.60	0.0
Minnedosa, Man.	1,690	28.02	29.81	-.13	52.8	+2.3	62.5	43.2	84	32	4.46	+3.10	0.0
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.59	29.82	-.10	52.4	+1.3	63.5	41.3	85	29	4.83	+3.60	0.0
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.33	29.93	+0.01	51.6	-1.5	64.1	39.1	85	28	4.24	+3.02	15.0
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.28	29.85	-.06	50.9	+2.5	61.9	40.0	74	32	3.00	+1.72	2.8
Battleford, Sask.	1,592	28.10	29.82	-.08	50.8	-1.0	62.3	39.4	78	31	2.80	+2.64	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	1,230	29.77	30.03	+0.2	54.6	-0.2	61.1	48.1	69	42	2.80	+0.64	0.0
Barkerville, B. C.	4,180												
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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MARCH.													
Victoria, B. C.	230	29.77	30.03	+0.06	43.9	+2.0	49.6	38.1	56	30	1.23	-1.89	1.9
MAY.													
Banff, Alb.	4,521	25.31	29.85	-.03	45.7	-1.3	59.5	31.9	75	22	1.36	-0.68	3.2
JUNE.													
Stonecliffe, Ont.	489	29.33					81.0		93		1.21	-1.95	0.0
Toronto, Ont.	379	29.58	29.97	.00	68.5	-5.1	79.9	57.1	90	45	2.15	-0.65	0.0
JULY.													
Sydney, C. B. I.	48	29.93	29.97	+0.04	66.7	+4.4	77.4	56.2	91	43	0.76	-2.89	0.0
AUGUST.													
Banff, Alb.	4,521	25.40	29.90	-.01	56.2	-0.1	72.0	40.5	83	31	1.40	-1.13	0.0
Calgary, Alb.	3,428	26.45	29.97	+0.06	61.3	+1.9	77.8	44.9	91	36	1.61	-0.53	0.0
Medicine Hat, Alb.	2,144	27.62	29.83	-.09	68.7	+3.0	84.6	52.9	96	43	0.53	-1.14	0.0

## SEISMOLOGICAL REPORTS FOR SEPTEMBER, 1921.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, Nov. 3, 1921.]

TABLE 1.—Noninstrumental earthquake reports, September, 1921.

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
CALIFORNIA.										
1921. Sept. 8	H. m.						Sec.			
	19 24	Pomona.....	34 05	117 45	3	2	1, 3	None.....	Felt by several.....	J. E. Adamson.
	19 25½	Calexico.....	32 41	115 30	4	1	60	do.....	Felt by many.....	W. S. Pratt.
	19 26	San Diego.....	32 40	117 10	3	2	1	do.....	Felt over city.....	U. S. Weather Bureau.
25	23 05	Hollister.....	36 45	121 20	3	3	5, 3, 2	do.....	Felt by several.....	Dr. E. D. Eddy.
26	22 45	San Bernardino.....	34 05	117 15	3	1		do.....	do.....	Associated Press.
		Ontario.....	34 05	117 40	4	1		do.....	do.....	Do.
	22 50	Claremont.....	37 48	122 26		1		do.....	do.....	S. H. Brackett.
		Riverside.....	33 38	117 21	Slight.	1		do.....	do.....	J. H. D. Cox.
	22 50½	Pomona.....	34 05	117 45	4	1		Faint.....	Felt by many.....	F. D. Young.
	22 32	Mount Wilson.....	34 13	118 16	3	1	1		Felt by several.....	W. P. Hoge.
29	16 35	Riverside.....	33 58	117 21	Slight.	1		None.....	do.....	J. H. D. Cox.
	16 37	Redlands.....	34 04	117 12	do.....	1		do.....	do.....	P. W. Moore.
	17 00	Riverside.....	33 58	117 21	5	1		do.....	Felt by many.....	Associated Press.
	17 30	San Jacinto.....	33 45	117 00	4	1		do.....	Felt by several.....	E. T. Tanner.
ILLINOIS.										
9	2 54	Waterloo.....	38 20	90 12	4	1	2-3	None.....	Felt by many.....	H. Bremser.
	3 05½	Chester.....	37 50	89 50		1	3	do.....	Felt by several.....	F. C. Kennedy.
	5 45	Waterloo.....	38 20	90 12	4	1	5	do.....	Felt by many.....	H. Bremser.
OREGON.										
22	19 20	Portland.....	45 30	122 40	4	1	10ca.	do.....	Felt by several.....	R. H. Desmond.
PENNSYLVANIA.										
27	4 32	Erie.....	42 05	80 10	3	1	45	do.....	Felt by two.....	H. O. Geren.
SOUTH DAKOTA.										
24	0 30	White Lake.....	43 45	99 00	4	1				Mrs. G. A. Rogers.
TENNESSEE.										
2	14 ca.	Statesville.....	36 10	86 15		Several.		Loud.....	Felt by several.....	W. B. Lester.
UTAH.										
13	9 30	Richfield.....	38 45	112 00	5	2	10	None.....	Felt by many.....	V. Erickson.
29	14 13	Kanosh.....	38 50	112 20	5	1	1-2	Yes.....	do.....	J. Cortsen.

TABLE 2.—Instrumental Reports, September, 1921.

[For significance of symbols and abbreviations, and for a description of stations and instruments, see the REVIEW for January, 1921, p. 47.]

Date.	Char-acter.	Phase.	Time.	Period T.	Amplitude.		Dis-tance.	Remarks.
					A <sub>s</sub>	A <sub>N</sub>		

## ALASKA. U. S. C. &amp; G. S. Magnetic Observatory, Sitka.

1921.		H. m. s.	Sec.	μ	μ	Km.	
Sept. 5	.....	20 24 20	18				No record on N.
	e <sub>s</sub> .....	20 28 16	19				
	M <sub>s</sub> .....	20 28 44	13	10			
	F <sub>s</sub> .....	20 35 ..					
11	.....	4 30 45					Do.
	e <sub>s</sub> .....	4 53 28	36				
	L <sub>s</sub> .....	4 56 18	30	10			
	M <sub>s</sub> .....	5 25 ..					
19	.....	4 20 58	19				Do.
	e <sub>s</sub> .....	4 24 37	13				
	M <sub>s</sub> .....	4 25 05	14	10			
	F <sub>s</sub> .....	4 33 ..					

Date.	Char-acter.	Phase.	Time.	Period T.	Amplitude.		Dis-tance.	Remarks.
					A <sub>s</sub>	A <sub>N</sub>		

## ARIZONA. U. S. C. &amp; G. S. Magnetic Observatory, Tucson.

1921.		H. m. s.	Sec.	μ	μ	Km.	
Sept. 8	.....	19 24 40	3				
	P <sub>s</sub> .....	19 24 49	3				
	P <sub>N</sub> .....	19 25 17					
	S <sub>s</sub> .....	19 25 30	14				
	L <sub>s</sub> .....	19 26 43	9	80			
	M <sub>s</sub> .....	19 25 58	12		70		
	M <sub>N</sub> .....	19 27 40					
	C <sub>s</sub> .....	19 28 36					
	C <sub>N</sub> .....	19 41 ..					
	F <sub>s</sub> .....						
	F <sub>N</sub> .....						
11	.....	4 21 09	4				No record on N.
	e <sub>s</sub> .....	4 25 10	10				
	e <sub>N</sub> .....	5 14 17	28				
	M <sub>s</sub> .....	5 16 40	20	20			
	F <sub>s</sub> .....	6 19 ..					
29	.....	14 18 56	3				Observer in room during earthquake.
	e <sub>s</sub> .....	14 19 31	5				
	M <sub>s</sub> .....	14 20 55	5	10			
	F <sub>s</sub> .....	14 24 ..					
	F <sub>N</sub> .....	14 25 ..					

TABLE 2.—Instrumental Reports, September, 1921—Continued.

COLORADO. Regis College, Denver.

1921. Sept. 8-9		H. m. s.	Sec.	$\mu$	$\mu$	Km.	
11	L <sub>N</sub> ...	3 19					Clear small waves at intervals on EW.
	L <sub>N</sub> ...	3 27					Weak but discern- able waves.
	M <sub>N</sub> ...	3 28		*1,000			
	M <sub>N</sub> ...	3 28	40		*1,000		
	F <sub>N</sub> ...	3 37					
	F <sub>N</sub> ...	3 34					
12	L <sub>N</sub> ...	3 59					Visible activity and thickening of pen marks.
	F <sub>N</sub> ...	4 15					
20	L <sub>N</sub> ...	12 28					Very weak and ir- regular waves.
	L <sub>N</sub> ...	12 28					
	F <sub>N</sub> ...	12 41					

\*Trace amplitude.

DISTRICT OF COLUMBIA. U. S. Weather Bureau, Washington.

1921. Sept. 5		H. m. s.	Sec.	$\mu$	$\mu$	Km.	
	P	20 09 27				9,200	
	S	20 19 49					
	eL	20 38 40	20				
	L	20 55 15	16				
	F	21 05					
8	e	19 29 20					No phases discern- ible; most pro- nounced between 19:40 and 19:47.
	F	19 55					
11	i	4 21 48					P and S not dis- tinguishable.
	L	4 35 40					
	L	5 25	30				
	L	5 40	18				
	F	6 35					
13	e	2 55 05					Faint.
	L	3 35	20				
	F	4 10					
19	e	4 37 20					
	L	4 46	16				
	F	5 10					
20	eL	0 14					
	F	0 30					

HAWAII. U. S. C. &amp; G. S. Magnetic Observatory, Honolulu.

1921 Sept. 3		H. m. s.	Sec.	$\mu$	$\mu$	Km.	
	P <sub>N</sub> ...	9 15 11					
	P <sub>N</sub> ...	9 15 31					
	S <sub>N</sub> ...	9 20 26					
	L <sub>N</sub> ...	9 23 00	12				
	M <sub>N</sub> ...	9 23 30	12	*600			
	M <sub>N</sub> ...	9 23 16	10		*1,000		
	C <sub>N</sub> ...	9 36 15					
	C <sub>N</sub> ...	9 36 50					
	F <sub>N</sub> ...	10 29					
	F <sub>N</sub> ...	10 14					
4	L <sub>N</sub> ...	23 52 40	12				
	L <sub>N</sub> ...	23 52 31	12				
	M <sub>N</sub> ...	23 53 31	12	*500			
	M <sub>N</sub> ...	23 53 31	12		*400		
	C <sub>N</sub> ...	23 54 16					
	F <sub>N</sub> ...	23 58					
5	P	20 01 58	8				P difficult to dis- tinguish from prevailing micro- seismic activity. Actual maxima oc- cur as follows: E, 20:19:47, ampl. 4.5 mm.; N, 20:19:31, ampl. 4.0 mm.
	IPR <sub>1</sub> ...	20 05 36					
	PR <sub>2</sub> ...	20 07 30					
	IS	20 12 36	11				
	PS <sub>N</sub> ...	20 13 18					
	SR <sub>1</sub> ...	20 19 03					
	SR <sub>1</sub> ...	20 18 45					
	L <sub>N</sub> ...	20 29 25	18				
	L <sub>N</sub> ...	20 29 47	17				
	M <sub>N</sub> ...	20 33 15	17	*2,000			
	M <sub>N</sub> ...	20 30 30	11		*1,900		
	C	20 52	9				
	F <sub>N</sub> ...	22 47					
	F <sub>N</sub> ...	23 02					
8	e <sub>N</sub> ...	19 40 28	10				
	e <sub>N</sub> ...	19 41 03	10				
	M <sub>N</sub> ...	19 44 33	8	*1,500			
	M <sub>N</sub> ...	19 41 54	10		*1,200		
	C	19 45	8				
	F <sub>N</sub> ...	19 52					
	F <sub>N</sub> ...	19 50					
11	P <sub>N</sub> ...	4 15 03	11				
	P <sub>N</sub> ...	4 15 08	6				
	PR <sub>1</sub> ...	4 19 10	11				
	PR <sub>1</sub> ...	4 19 18	18				
	S <sub>N</sub> ...	4 26 00	17				
	S <sub>N</sub> ...	4 26 24	20				
	SR <sub>1</sub> ...	4 32 20	30				
	L <sub>N</sub> ...	4 45 56	34				
	L <sub>N</sub> ...	4 39 50	40				
	M <sub>N</sub> ...	4 50 50	14	*6,300			
	M <sub>N</sub> ...	4 43 20	35		*7,000		
	C <sub>N</sub> ...	5 12 18	20				
	C <sub>N</sub> ...	5 28	19				
	F <sub>N</sub> ...	7 35	15				
	F <sub>N</sub> ...	7 15	16				
13	e <sub>N</sub> ...	2 58 11					Recording appar- atus of N out of adjustment.
	L <sub>N</sub> ...	3 38 00	22				
	L <sub>N</sub> ...	3 37	22				
	M <sub>N</sub> ...	3 42 20	18	*1,500			
	M <sub>N</sub> ...	3 43	20		*3,000		
	F <sub>N</sub> ...	4 55					
19	e <sub>N</sub> ...	4 18 51					
	L <sub>N</sub> ...	4 20 20	21				
	L <sub>N</sub> ...	4 20 44	15				
	M <sub>N</sub> ...	4 21 43	15	*5,800			
	M <sub>N</sub> ...	4 21 29	14		*4,200		
	C <sub>N</sub> ...	4 30 30	11				
	C <sub>N</sub> ...	4 28 44	15				
	F <sub>N</sub> ...	6 12					
	F <sub>N</sub> ...	6 34					
19	P	23 25 05	6				
	S	23 31 50	9				
	L <sub>N</sub> ...	23 35 22	14				
	L <sub>N</sub> ...	23 35 05	15				
	M <sub>N</sub> ...	23 38 48	11	*10,500			
	M <sub>N</sub> ...	23 38 38	10		*7,500		
	C <sub>N</sub> ...	23 42	15				
	C <sub>N</sub> ...	23 44					
	F <sub>N</sub> ...	2 12					
	F <sub>N</sub> ...	2 16					
20	e <sub>N</sub> ...	19 09 42	19				
	M <sub>N</sub> ...	19 12 34	10	*1,700			
	M <sub>N</sub> ...	19 12 44	8		*1,400		
	C <sub>N</sub> ...	19 13 23					
	C <sub>N</sub> ...	19 15 23					
	F <sub>N</sub> ...	19 39					
	F <sub>N</sub> ...	19 49					
23	e <sub>N</sub> ...	2 32 21	16				
	M <sub>N</sub> ...	2 35 18	11	*1,200			
	M <sub>N</sub> ...	2 35 10	10		*1,000		
	F <sub>N</sub> ...	3 08					
	F <sub>N</sub> ...	3 05					
29	e <sub>N</sub> ...	13 28 43					
	e <sub>N</sub> ...	13 28 48					
	L <sub>N</sub> ...	13 30 42	15				
	L <sub>N</sub> ...	13 30 35	13				
	M <sub>N</sub> ...	13 32 57	15	*1,300			
	M <sub>N</sub> ...	13 33 05	15		*1,100		
	F <sub>N</sub> ...	13 43					
	F <sub>N</sub> ...	13 37					

\* Trace amplitude

TABLE 2.—Instrumental Reports, September, 1921—Continued.

## ILLINOIS. U. S. Weather Bureau, Chicago.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 5	P.		20 08 45					
	S.		20 19 20					
	L.		20 32 45	30				
	L.		20 38 ..	18				
	F.		22 30 ..					
8	P.		19 28 25				2,700	
	S.		19 30 45					
	L.		19 38 15					
	F.		20 05 ..					
11	L.		4 21 08					P and S not distinguishable owing to distance of quake.
	L.		4 34 55					
	F.		8 ca.					
13	e.		2 55 20					
	L.		3 30 ..	25				
	L.		3 40 ..	18				
	F.		6 10 ca.					
19	e.		4 24 20					
	L.		4 33 45					
	F.		5 40 ..					
19	P.		23 41 30					
	S.		23 50 15					
	eL.		0 04 30	24				
	L.		0 14 ..	16				
20	F.		2 ca.					
21	L.		12 01 00	18				
	F.		12 40 ..					

## MARYLAND. U. S. C &amp; G. S. Magnetic Observatory, Cheltenham.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 5	L <sub>N</sub>		20 36 16	23				Very faint. No record on E.
	M <sub>N</sub>		20 58 31	13		10		
	F <sub>N</sub>		21 20 ..					
11	i <sub>N</sub>		4 21 29	6				L may beat 5:20:50. No record on E.
	e <sub>N</sub>		4 25 39	12				
	L <sub>N</sub>		4 50 53	24				
	M <sub>N</sub>		5 34 57	22		100		
	F <sub>N</sub>		6 29 ..					
19	e <sub>N</sub>		4 37 52	30				No record on E.
	e <sub>N</sub>		4 43 51	14				
	e <sub>N</sub>		4 46 03	18				
	M <sub>N</sub>		4 46 30	15		10		
	F <sub>N</sub>		5 05 ..					

## MISSOURI. St. Louis University, St. Louis.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 8	i.		19 34 54					Microscopic.
	L.		19 37 ..	3	*6000			
	L.		19 42 ..					
	F.							
11	eP.		4 21 24					
	S.		4 26 42?					
	L.		4 37 18?					
	L.		5 05 24					
	L.		5 09 54					
	L.		5 13 36					
	L.		5 27 ..					
	M <sub>N</sub>		5 30 18	18	*12000			
	M <sub>N</sub>		5 32 18	24		*12000		

\* Trace amplitude.

## NEW YORK. Fordham University, New York.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 11	P <sub>N</sub>		4 21 40					
	P <sub>N</sub>		4 21 32					
	S <sub>N</sub>		4 25 36					
	M <sub>N</sub>		5 16 00					
20	L <sub>N</sub>		0 14 30					L of small amplitude.
	M <sub>N</sub>		0 22 30					

## CANAL ZONE. Panama Canal, Balboa Heights.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 11								Slight tremors from a distant quake between 4:22 and 6:20.

## PORTO RICO. U. S. C. &amp; G. S. Magnetic Observatory, Vieques.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 11	e <sub>N</sub>		4 27 35	5				No definite M on E.
	e <sub>N</sub>		4 27 06	5				
	e <sub>N</sub>		4 31 22	8				
	e <sub>N</sub>		4 59 20	28				
	M <sub>N</sub>		5 01 00	26		10		
	F <sub>N</sub>		6 05 ..					
	F <sub>N</sub>		5 46 ..					

## VERMONT. U. S. Weather Bureau, Northfield.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 5	eL.		20 39 ..					
	L.		20 45 ..	18				
	F.		21 20 ca.					
11	i.		4 21 20					
	L.		5 10 ..	60				
	L.		5 18 ..	35				
	L.		5 33 ..	16				
	F.		6 25 ..					

## CANADA. Dominion Observatory, Ottawa.

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Sept. 5	e <sub>N</sub>		20 14 32					Micros obscure NS.
	e <sub>N</sub>		20 18 53					
	e <sub>N</sub>		20 23 41					
	e <sub>N</sub>		20 25 13					
	eL <sub>N</sub>		20 28 30					
	L <sub>N</sub>		20 31 ..	13				
	L <sub>N</sub>		20 37 24	24				
	L <sub>N</sub>		20 47 ..	15				
	L <sub>N</sub>		20 51 ..	13				
	F <sub>N</sub>		21 07 ..	15				
8	i <sub>N</sub>		19 40 56					Small irregular periods.
	i <sub>N</sub>		19 41 08					
	i <sub>N</sub>		19 41 26					
	i <sub>N</sub>		19 42 02					
	eL <sub>N</sub>		19 43 45					
	L <sub>N</sub>		19 45 ..					
	F <sub>N</sub>		20 20 ..					
11	O.		4 06 25				12,340	
	iP.		4 21 15					
	eS?		4 33 49					
	eL <sub>N</sub>		5 01 ..					
	L <sub>N</sub>		5 05 ..	60				
	L <sub>N</sub>		5 12 ..	52				
	L <sub>N</sub>		5 20 ..	27				
	L <sub>N</sub>		5 30 ..	19				
	L <sub>N</sub>		5 40 ..	18				
	L <sub>N</sub>		5 53 ..	18				
13	L <sub>N</sub>		6 00 ..	17				
	L <sub>N</sub>		6 08 ..	17				
	L <sub>N</sub>		6 10 ..	17				
	L <sub>N</sub>		6 18 ..	16				
	L <sub>N</sub>		6 23 ..	16				
	L <sub>N</sub>		6 28 ..	16				
	L <sub>N</sub>		6 50 ..	15				
	L <sub>N</sub>		7 06 ..	15				
	F <sub>N</sub>		7 30 ..					
19	O.		2 48 00				4,370	
	P.		2 55 45					
	S.		3 01 53					
	SR <sub>N</sub>		3 04 15					
	i <sub>N</sub>		3 05 18					
	eL <sub>N</sub>		3 09 ..					
	L <sub>N</sub>		3 15 ..	17				
	L <sub>N</sub>		3 36 ..	18				
	L <sub>N</sub>		3 47 ..	15				
	F <sub>N</sub>		4 23 ..	18				
19	e <sub>N</sub>		4 31 42					
	eL <sub>N</sub>		4 35 ..					
	L <sub>N</sub>		4 42 ..	21				
	L <sub>N</sub>		4 44 ..	15				
	F <sub>N</sub>		5 ca.					
19	e <sub>N</sub>		23 45 45					Micros obscure NS. No traces of P on either component.
	S <sub>N</sub>		23 52 15					
	eL <sub>N</sub>		0 01 ..					
	L <sub>N</sub>		0 11 ..	30				
	L <sub>N</sub>		0 15 ..	22				
20	L <sub>N</sub>		0 25 ..	17				
	L <sub>N</sub>		0 44 ..	15				
	L <sub>N</sub>		0 48 ..	15				
	L <sub>N</sub>		0 54 ..	15				
	F <sub>N</sub>		1 ca.					
20	eL <sub>N</sub>		19 49 ..	21				Sinusoidal L waves.
21	F.		19 56 ..					Small amplitude. Small amplitude; micros obscure NS.
	e <sub>N</sub>		(11 25 34)					
	eL <sub>N</sub>		11 50 ..					
	L <sub>N</sub>		11 54 ..	21				
	F <sub>N</sub>		12 17 ..					

TABLE 2.—Instrumental Reports, September, 1921—Continued.

CANADA. Dominion Meteorological Service, Toronto.

1921.		H. m. s.	Sec.	μ	μ	Km.
Sept. 5	e.	20 27 24				
	L.	20 34 36				
	IL.	20 40 12				
	eL.	20 42 18				
	IL.	20 50 36				
	M.	20 50 54				
	F.	21 24 36		*900		
8						
11	i.	4 21 54				
	i.	4 25 06				
	e.	4 28 54				
	e.	4 35 24				
	i.	4 38 42				
	L.	4 40 30				
	IL.	4 53 12				
	eL.	5 02 42				
	eL.	5 21 12				
	M.	5 55 12		*3,200		
	eL.	6 20 36				
	L.	6 41 00				
	eL.	6 59 00				
	F.	7 18 48				
13						
19	eL.	4 39 42				
	M.	4 43 48		*600		
	eL.	4 50 18				
	M2.	4 53 54		*500		
	F.	5 13 24				
19	P?	23 41 36?				
	eS?	23 51 00				
20	eL.	0 15 24				
	M.	0 20 48		*1,800		
	L.	0 40 54				
	F.	1 10 42				
20	L.	1 39 00				
	F.	1 51 00		*100		
20	eL.	19 50 54		*200		
	F.	20 02 12				
21	L?	12 13 18				
	eL.	12 18 48				
	M.	12 19 12		*200		
23	L.	2 52 54		*50		
	F.	3 00 54				

Clock stopped.

Difficult seismo-gram to analyse.

Clock stopped.

CANADA. Dominion Meteorological Service, Victoria.

1921.		H. m. s.	Sec.	μ	μ	Km.
Sept. 5	S.	20 13 16				
	L.	20 17 45				
	M.	20 28 39		*750		
	F.	21 39 43				
8	P & L.	19 31 57				650?
	M.	19 33 25		*500		
	F.	19 37 21				
11	P?	4 15 19				4,650?
	S.	4 21 42				
	L.	4 29 05				
	IL.	5 21 42				
	IL.	5 26 18		*4,000		
	M.	5 28 35				
	IL.	5 31 06				
	eL.	6 00 04				
	F.	7 19 26				
	VERTICAL.					
	S.	4 20 50				
	L.	4 31 19	25			
	M.	5 03 19	25	3		
13	S.	2 48 28				
	L.	2 56 50				
	M.	3 58 48		*750		
	F.	5 25 51				
19	L?	4 17 37				
	M.	4 22 02		*750		
	F.	4 58 25				
19	P.	23 30 53				
	S.	23 39 15				
	L.	23 50 33				
	M.	23 58 55		*1,500		6,860
	F.	0 56 27				
20	L.	1 41 30				
	F.	1 51 30		*100		
20	L.	19 30 28				
	M.	19 32 58		*200		
	F.	19 44 58				
21	L.	12 09 25				
	M.	12 15 49		*100		
	F.	12 30 05				
23	L.	2 53 50				
	M.	2 55 48		*200		
	F.	3 02 42				
26	M.	21 02 57		*50		
29	S or L.	13 28 47				
	L?	13 35 40				
	M.	13 41 34		*250		
	F.	13 52 53				

Well-defined vibrations, 4h29m05s to 6h06m04s.

\*Trace amplitude.

Reports for September, 1921, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

CALIFORNIA. *Theosophical University*, Point Loma.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

MASSACHUSETTS. *Harvard University*, Cambridge.

NEW YORK. *Canisius College*, Buffalo; *Cornell University*, Ithaca.

TABLE 3.—Late reports (instrumental).

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Aug. 7	i	.....	6 33 09	.....	.....	.....	.....	Felt in Virginia.
	is	.....	6 33 36	.....	.....	.....	.....	
	F	.....	6 35 ..	.....	.....	.....	.....	
19	ea	.....	8 34 40	.....	.....	.....	.....	Heavy micros.
	en	.....	8 35 00	.....	.....	.....	.....	
	eL	.....	8 38 48	16	.....	.....	.....	
	eL	.....	8 39 00	.....	.....	.....	.....	
	F	.....	8 56 ..	.....	.....	.....	.....	
23	P	.....	20 25 29	.....	.....	.....	.....	
	S	.....	20 32 ..	.....	.....	.....	.....	
	eL	.....	20 38 18	.....	.....	.....	.....	
	eL	.....	20 38 18	.....	.....	.....	.....	
	L	.....	20 40 ..	22	.....	.....	.....	
	L	.....	20 40 27	22	.....	.....	.....	
	F	.....	21 05 ..	.....	.....	.....	.....	
29	e	.....	19 09 15	.....	.....	.....	.....	
	F	.....	19 20 ..	.....	.....	.....	.....	

MISSOURI. *St. Louis University, St. Louis.*

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Aug. 23	eL	.....	20 37 ..	.....	.....	.....	.....	P and S not found.
	L	.....	20 42 36	.....	.....	.....	.....	
	M	.....	20 46 12	6	*0,000	.....	.....	
	F	.....	21 00 00	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Toronto.*

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Aug. 14	e	.....	14 14 18	.....	.....	.....	.....	
	eL	.....	14 17 48	.....	*200	.....	.....	
	eL	.....	14 27 12	.....	.....	.....	.....	
19	eL	.....	8 41 18	.....	.....	.....	.....	
	M	.....	8 42 00	.....	*500	.....	.....	
	F	.....	9 02 00	.....	.....	.....	.....	
23	P	.....	20 24 18	.....	.....	.....	.....	Time of P doubtful; instrument being inspected.
	S	.....	20 29 42	.....	.....	.....	.....	
	iL	.....	20 34 05	.....	.....	.....	.....	
	iL	.....	20 39 12	.....	.....	.....	.....	
	M	.....	20 41 06	.....	*2,000	.....	3,610	
	eL	.....	20 58 24	.....	.....	.....	.....	
	F	.....	21 56 18	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Victoria.*

1921.			H. m. s.	Sec.	$\mu$	$\mu$	Km.	
Aug. 14	L	.....	14 23 45	.....	.....	.....	.....	Very gradual and slow waves of disturbance.
	eL	.....	14 37 27	.....	*50	.....	.....	
17	L	.....	23 55 46	.....	.....	.....	.....	
18	M	.....	00 01 41	.....	*250	.....	.....	
	F	.....	00 13 29	.....	.....	.....	.....	
23	S?	.....	20 34 32	.....	.....	.....	.....	
	L	.....	20 38 09	.....	.....	.....	.....	
	iL	.....	20 42 05	.....	.....	.....	.....	
	M	.....	20 46 02	.....	*2,700	.....	.....	
	eL	.....	21 00 00	.....	.....	.....	.....	
	F	.....	21 15 02	.....	.....	.....	.....	

\* Trace amplitude.

Reports for September, 1921, have not been received from the following stations:  
 ALABAMA. Spring Hill College, Mobile.  
 CALIFORNIA. University of California, Los Angeles.  
 DISTRICT OF COLUMBIA. Georgetown University, Washington.  
 ILLINOIS. University of Chicago, Chicago.  
 MASSACHUSETTS. Harvard University, Cambridge.  
 NEW YORK. Columbia College, Buffalo; Cornell University, Ithaca.



Chart II. Tracks of Centers of High Areas, September, 1921.  
(Plotted by Wilfred P. Day.)

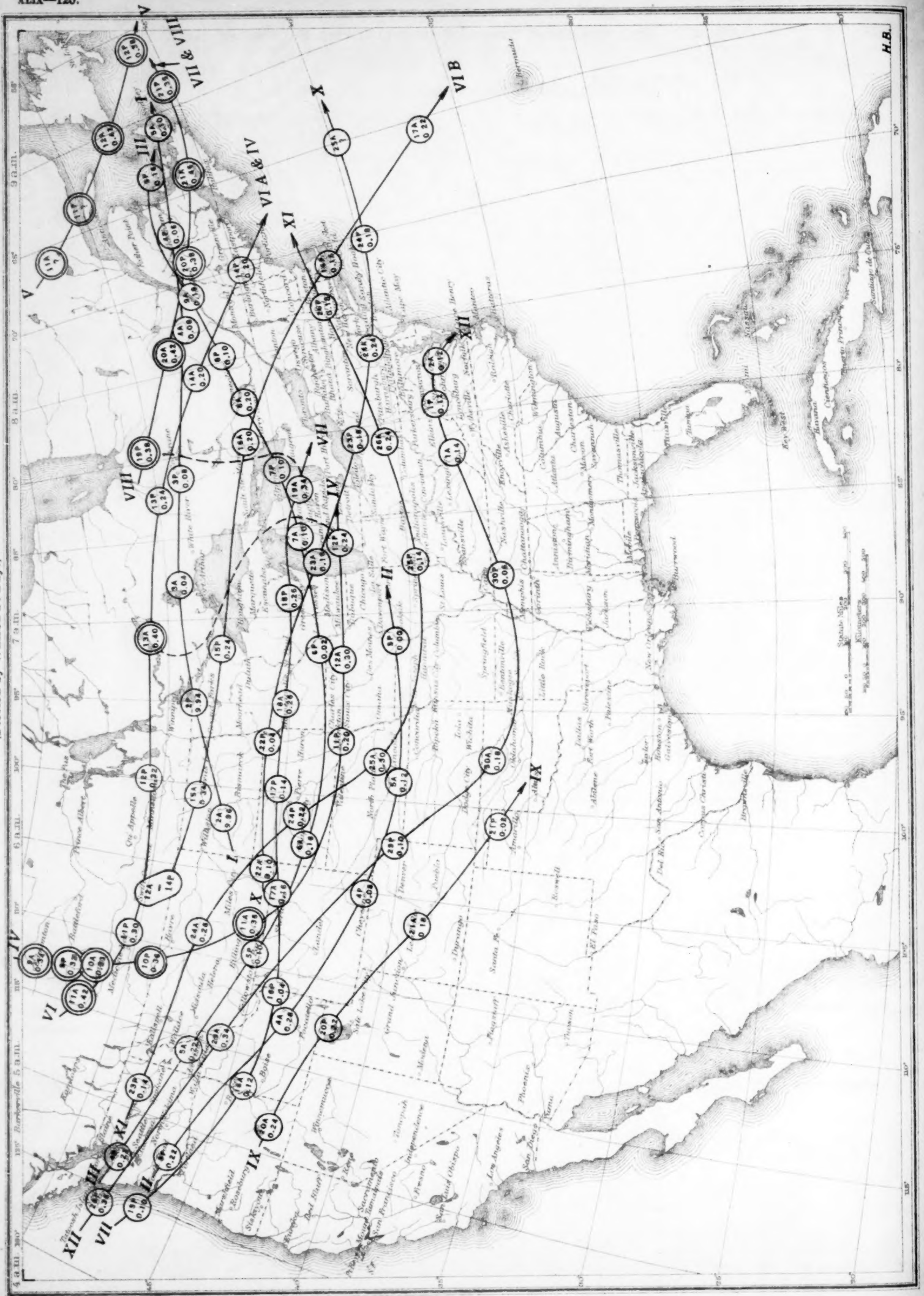


Chart III. Tracks of Centers of Low Areas, September, 1921.  
(Plotted by Wilfred P. Day.)

Chart III. Tracks of Centers of Low Areas, September, 1921.  
(Plotted by Wilfred P. Day.)

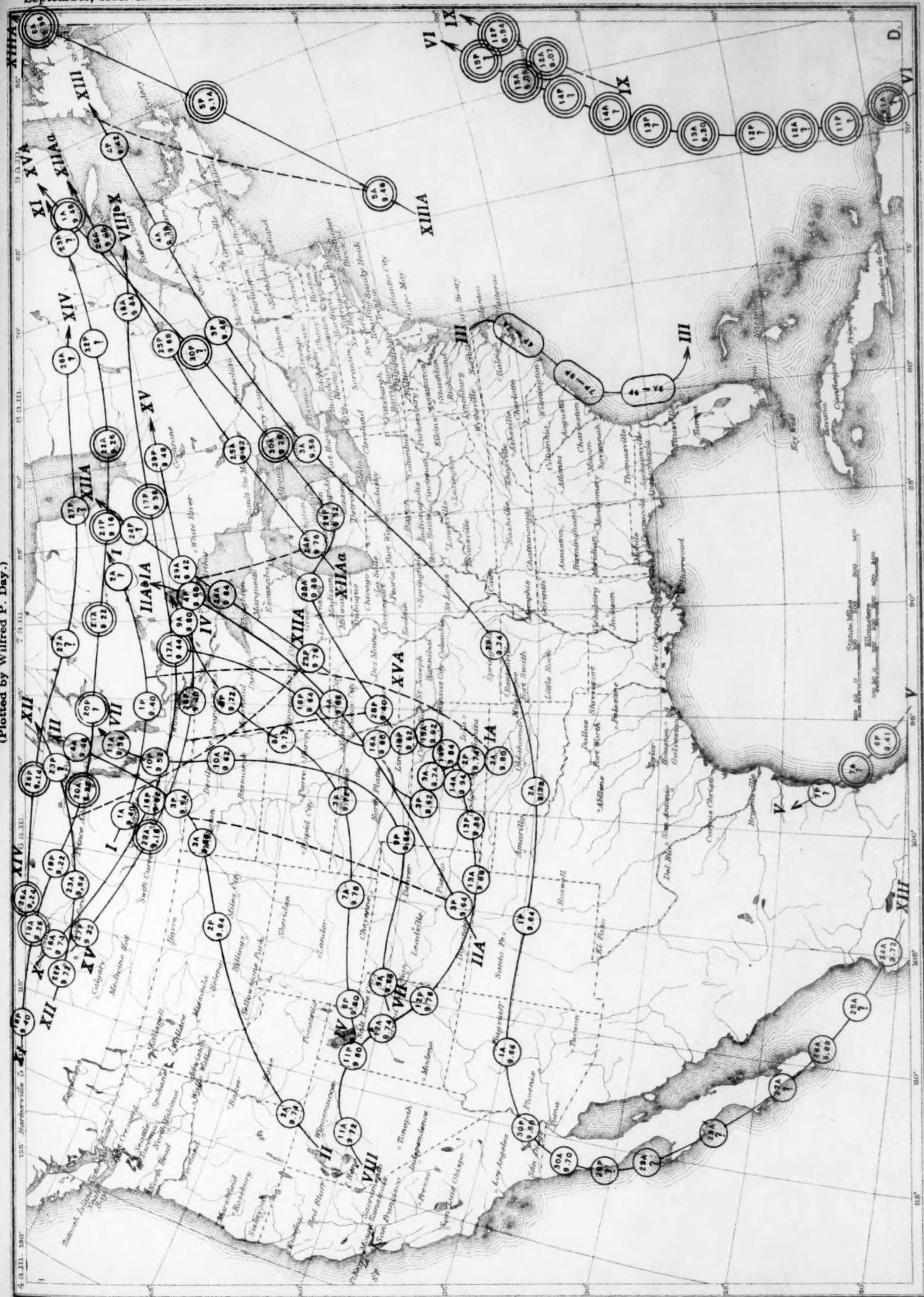


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, September, 1921.

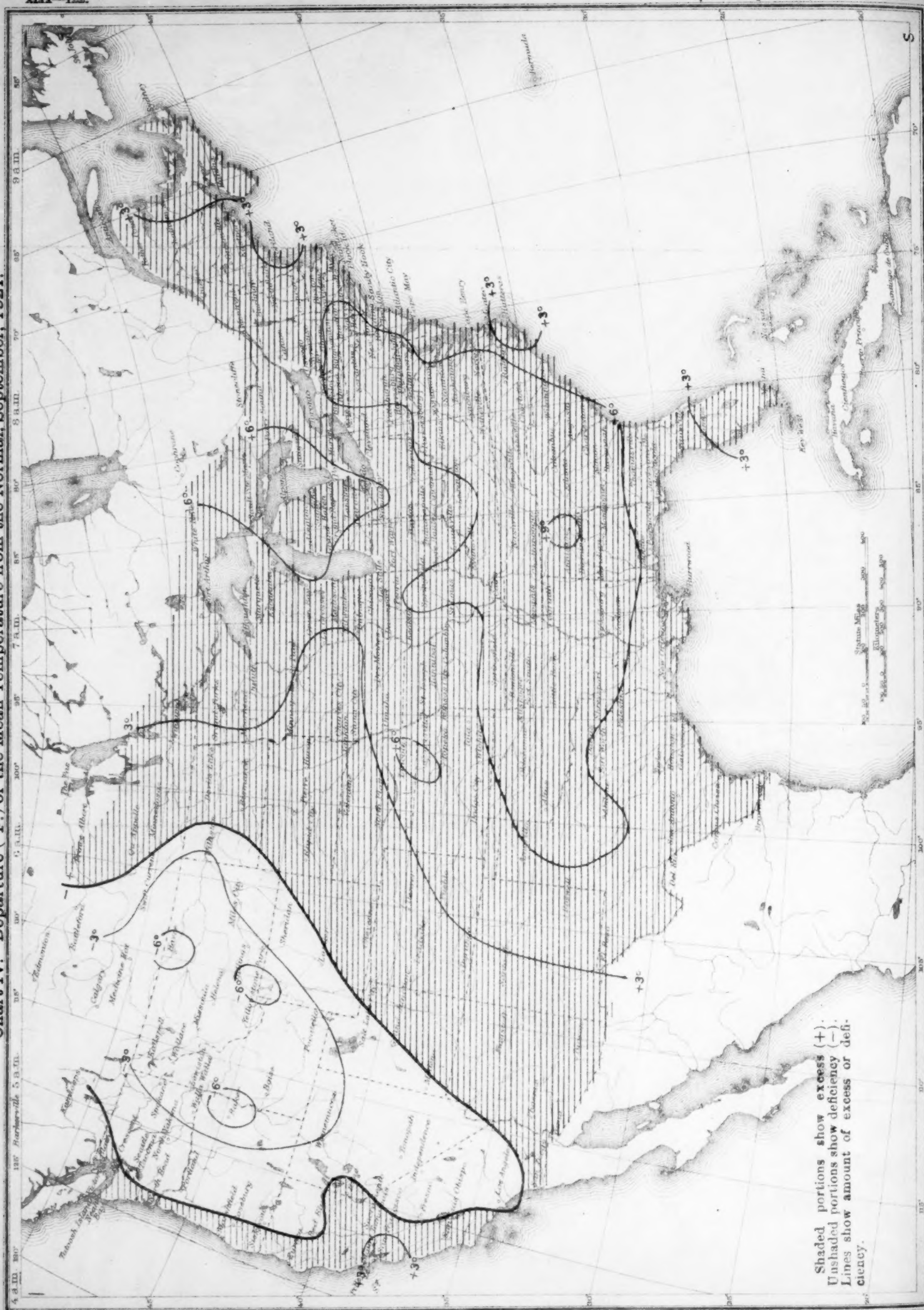


Chart V. Total Precipitation, Inches, September, 1921.



Chart VI. Percentage of Clear Sky between Sunrise and Sunset, September, 1921.

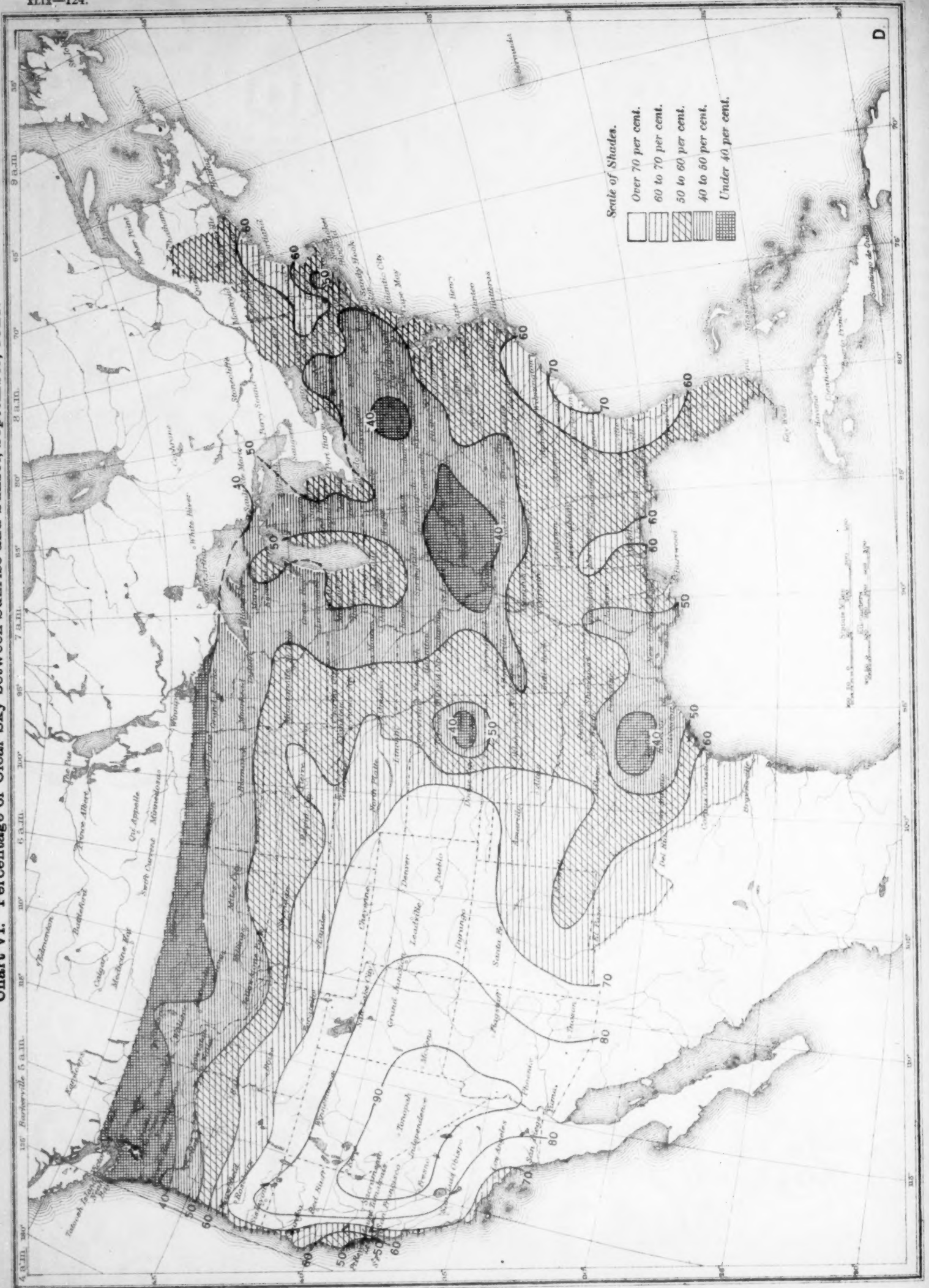


Chart VII. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, September, 1921.

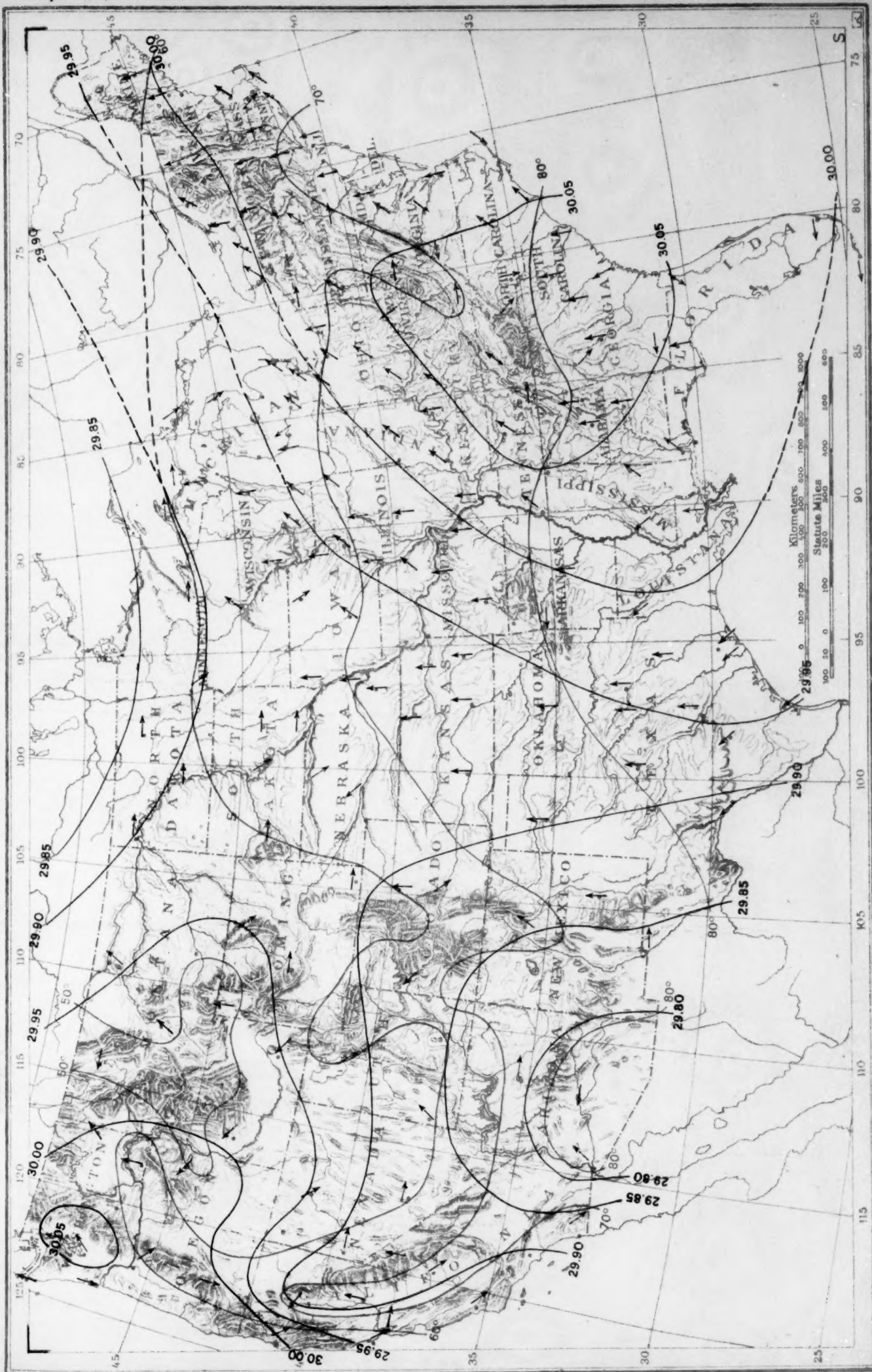




Chart IX. Weather Map of North Atlantic Ocean, September 11, 1921.  
(Plotted by F. A. Young.)

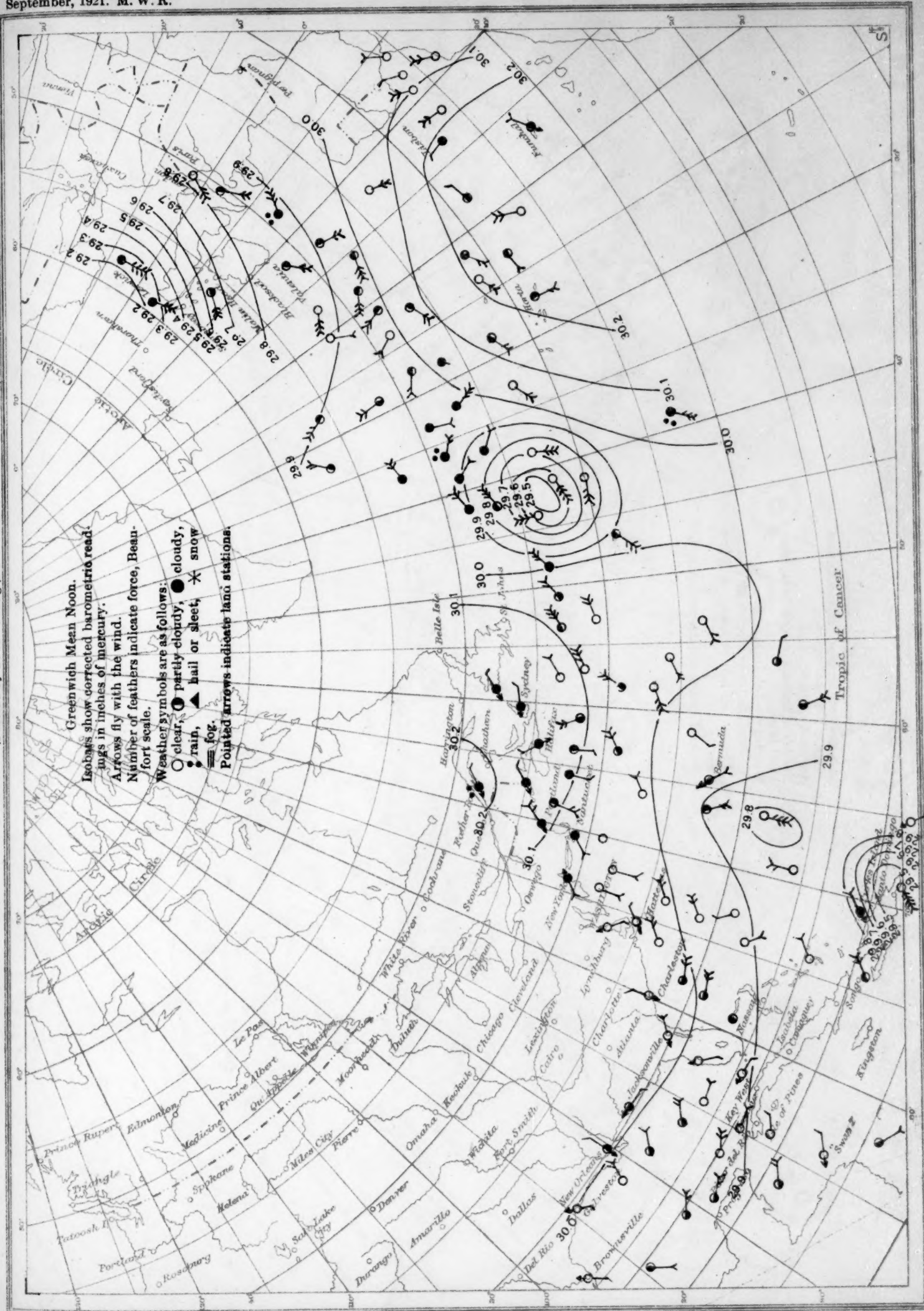


Chart X. Weather Map of North Atlantic Ocean, September 12, 1921.

(Plotted by F. A. Young.)

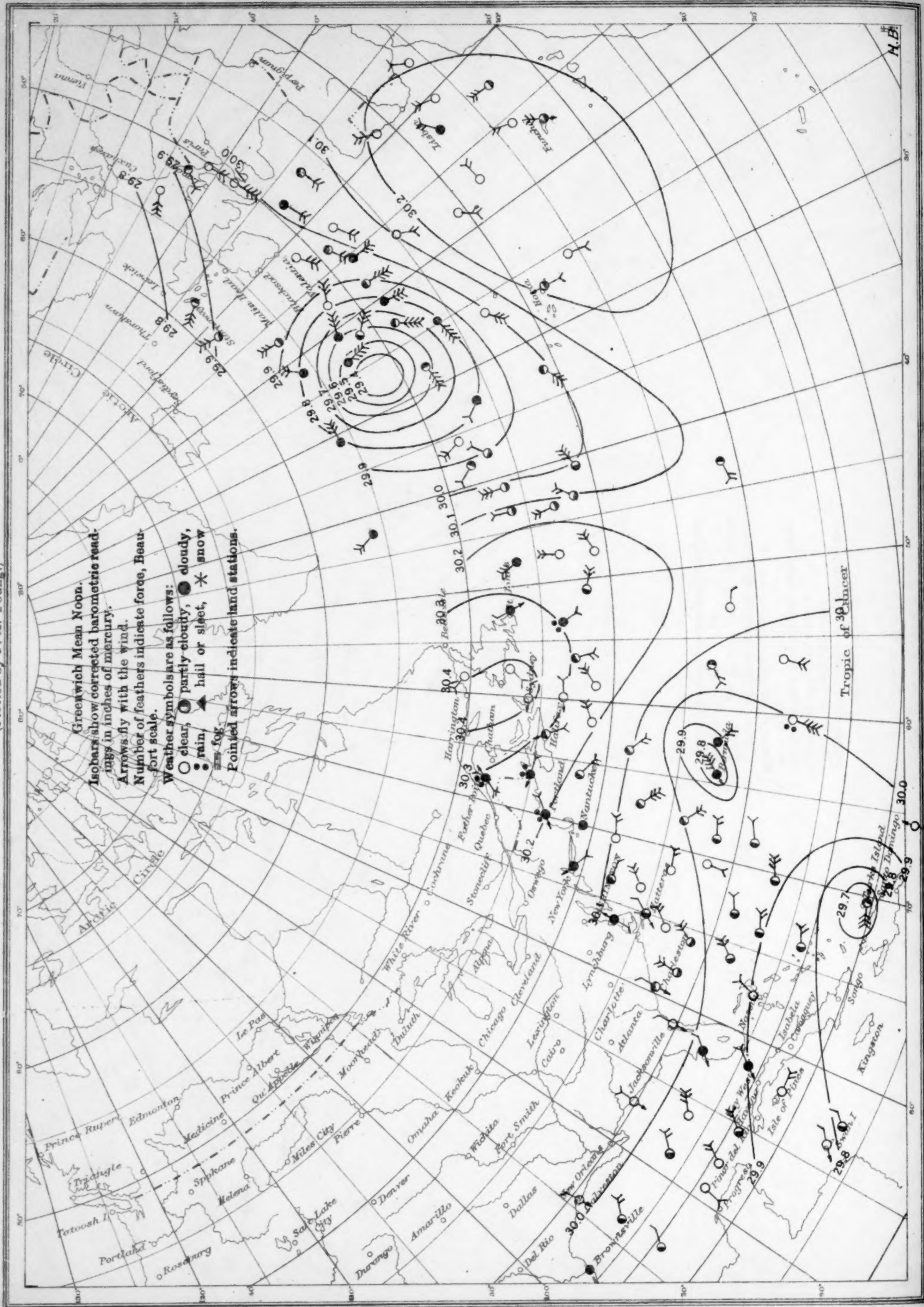


Chart XI. Weather Map of North Atlantic Ocean, September 13, 1921.

(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, September 13, 1921.

(Plotted by F. A. Young.)

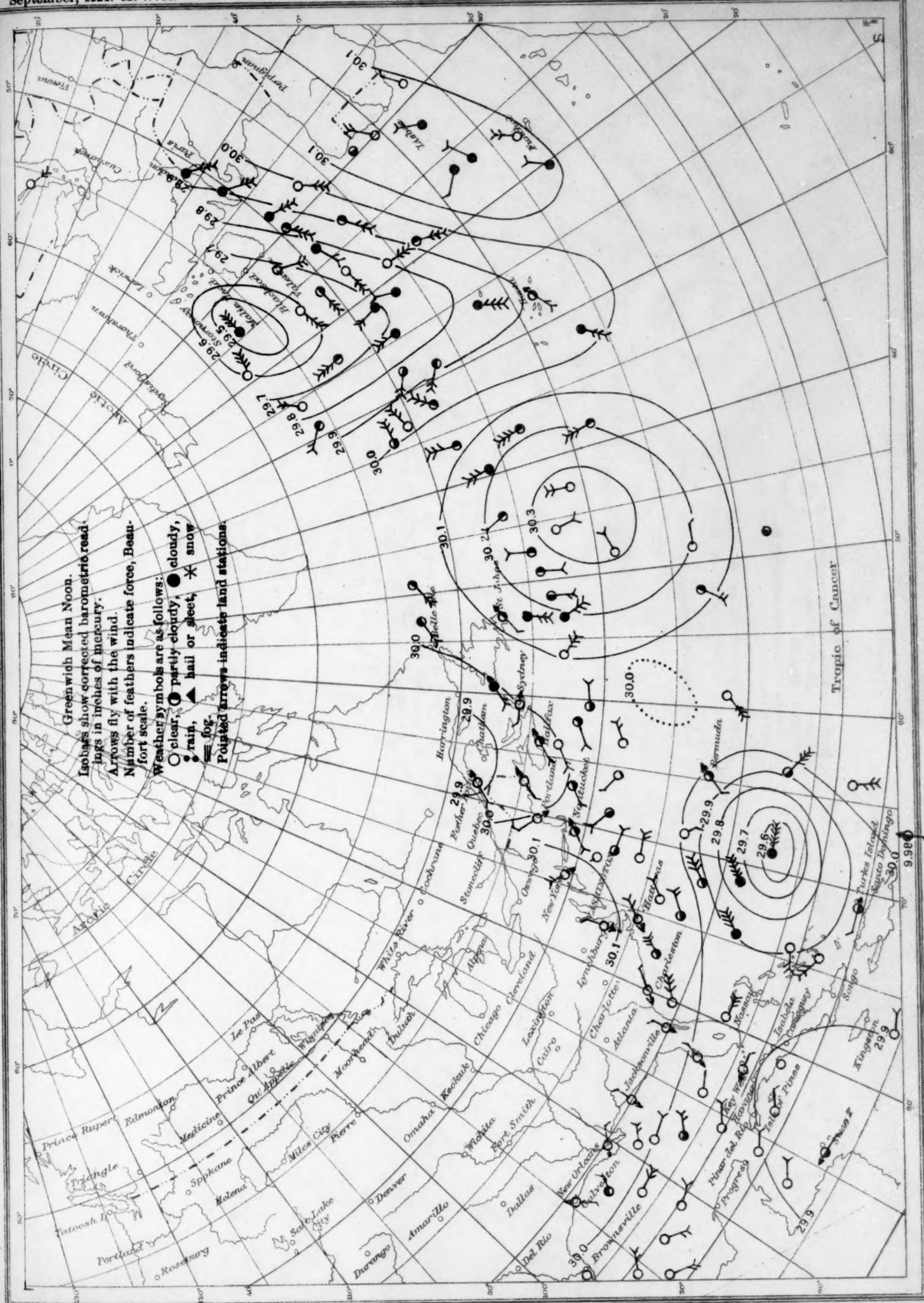


Chart XII. Weather Map of North Atlantic Ocean, September 14, 1921.

(Plotted by F. A. Young.)

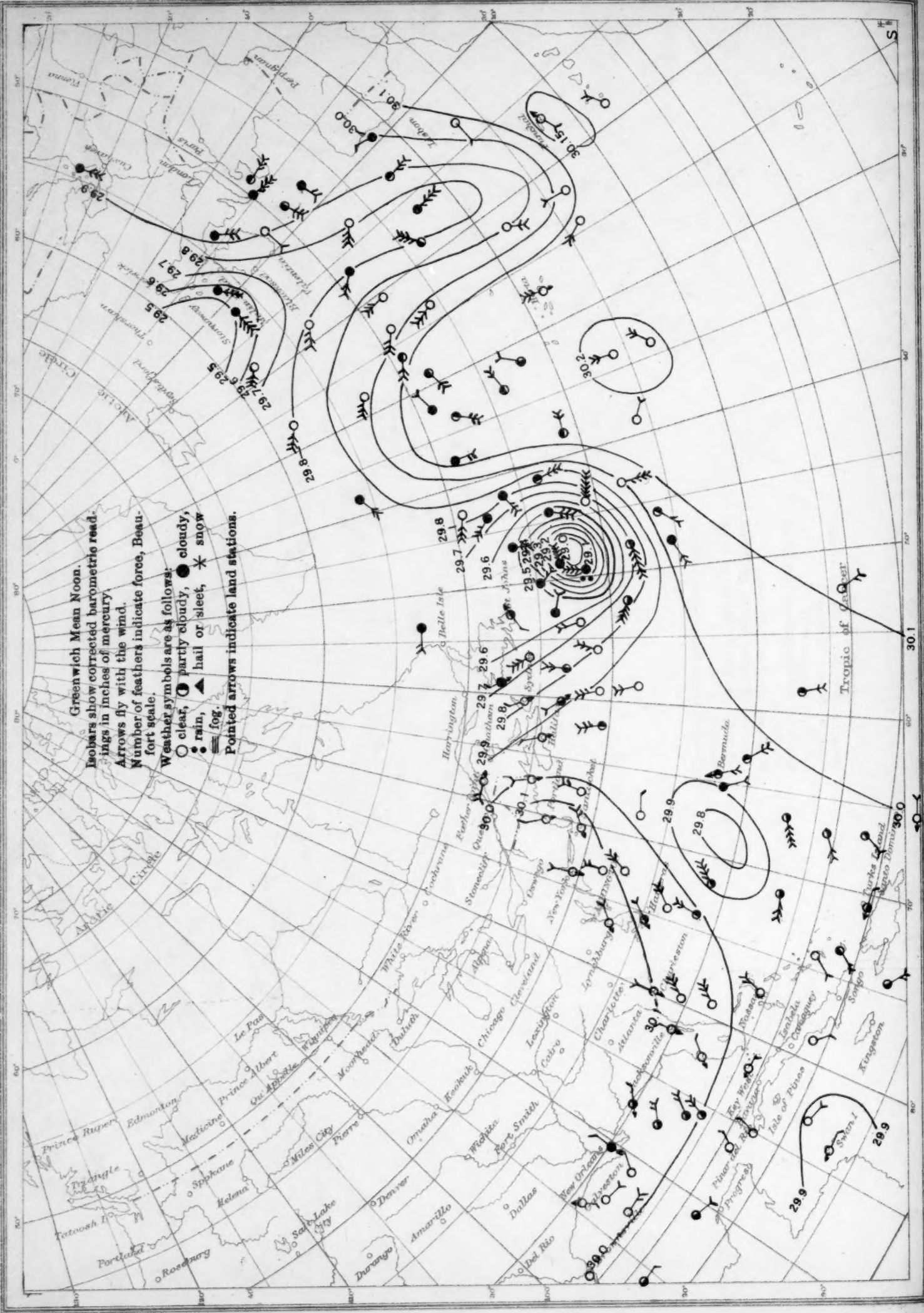


Chart XIII. Weather Map of North Atlantic Ocean, September 15, 1921.

(Plotted by F. A. Young.)

Chart XIII. Weather Map of North Atlantic Ocean, September 15, 1921.

(Plotted by F. A. Young.)

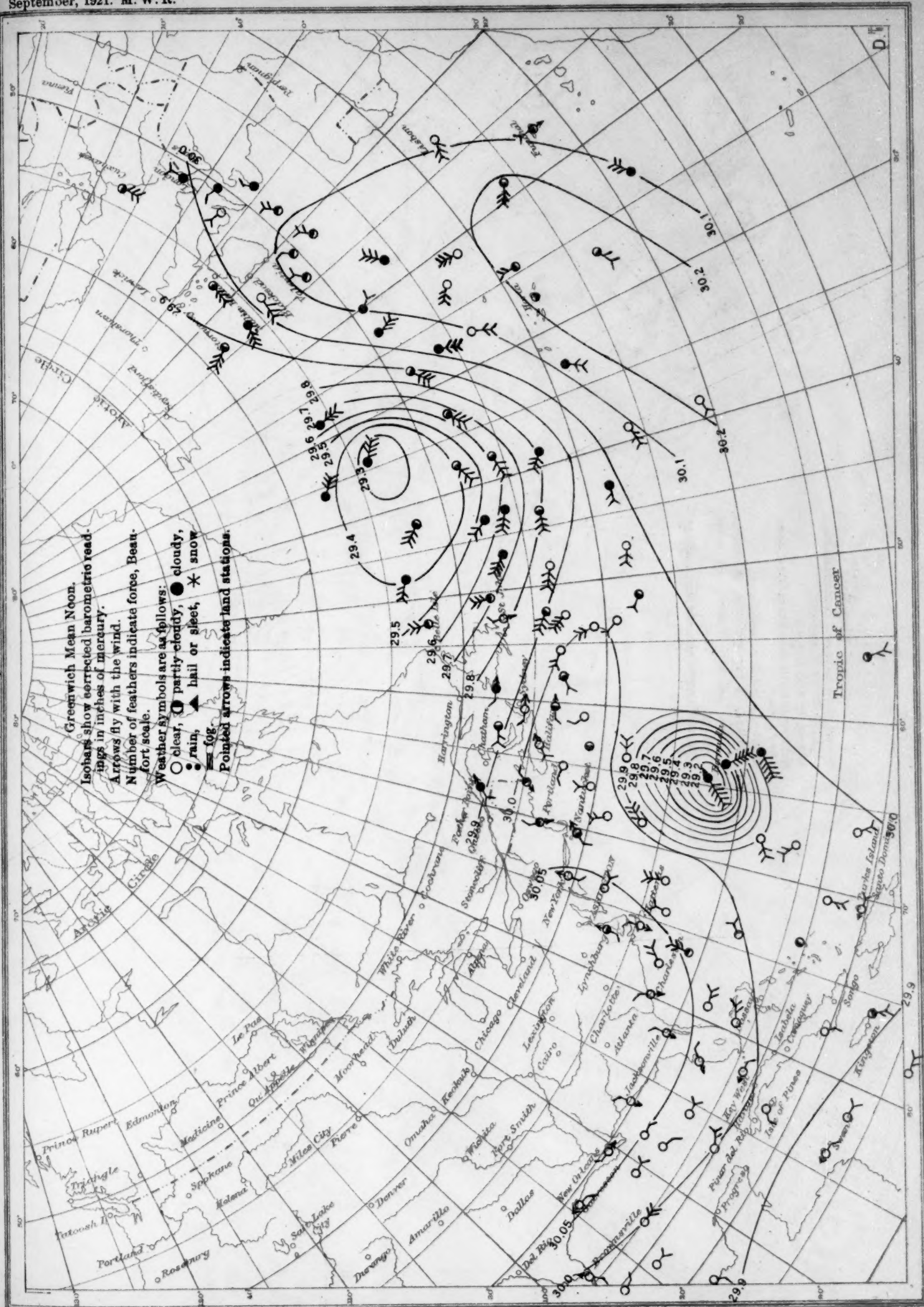


Chart XIV. Weather Map of North Atlantic Ocean, September 16, 1921.

(Plotted by F. A. Young.)

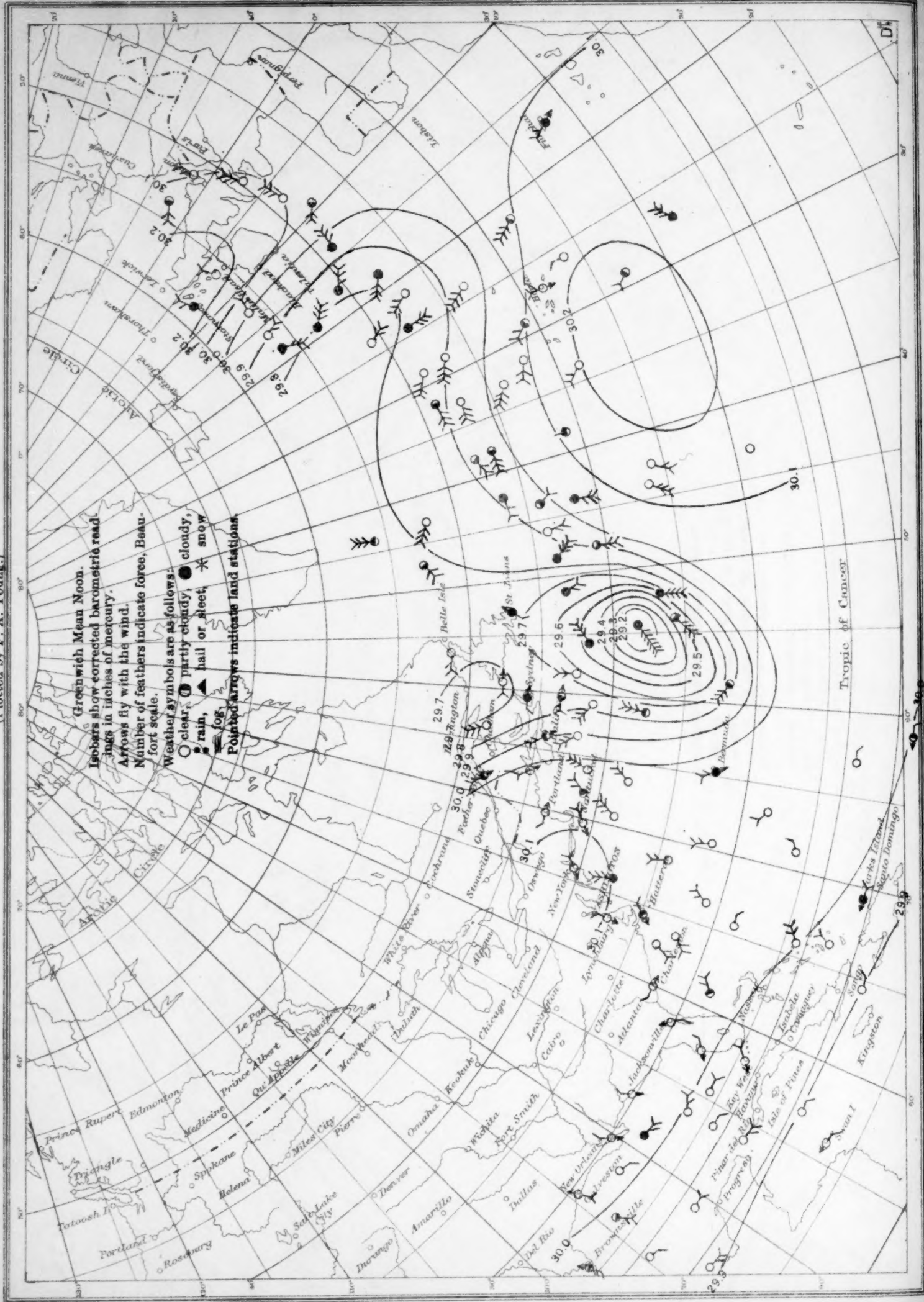


Chart XV. Weather Map of North Atlantic Ocean, September 17, 1921.

(Plotted by F. A. Young.)

Chart XV. Weather Map of North Atlantic Ocean, September 17, 1921.  
(Plotted by F. A. Young.)

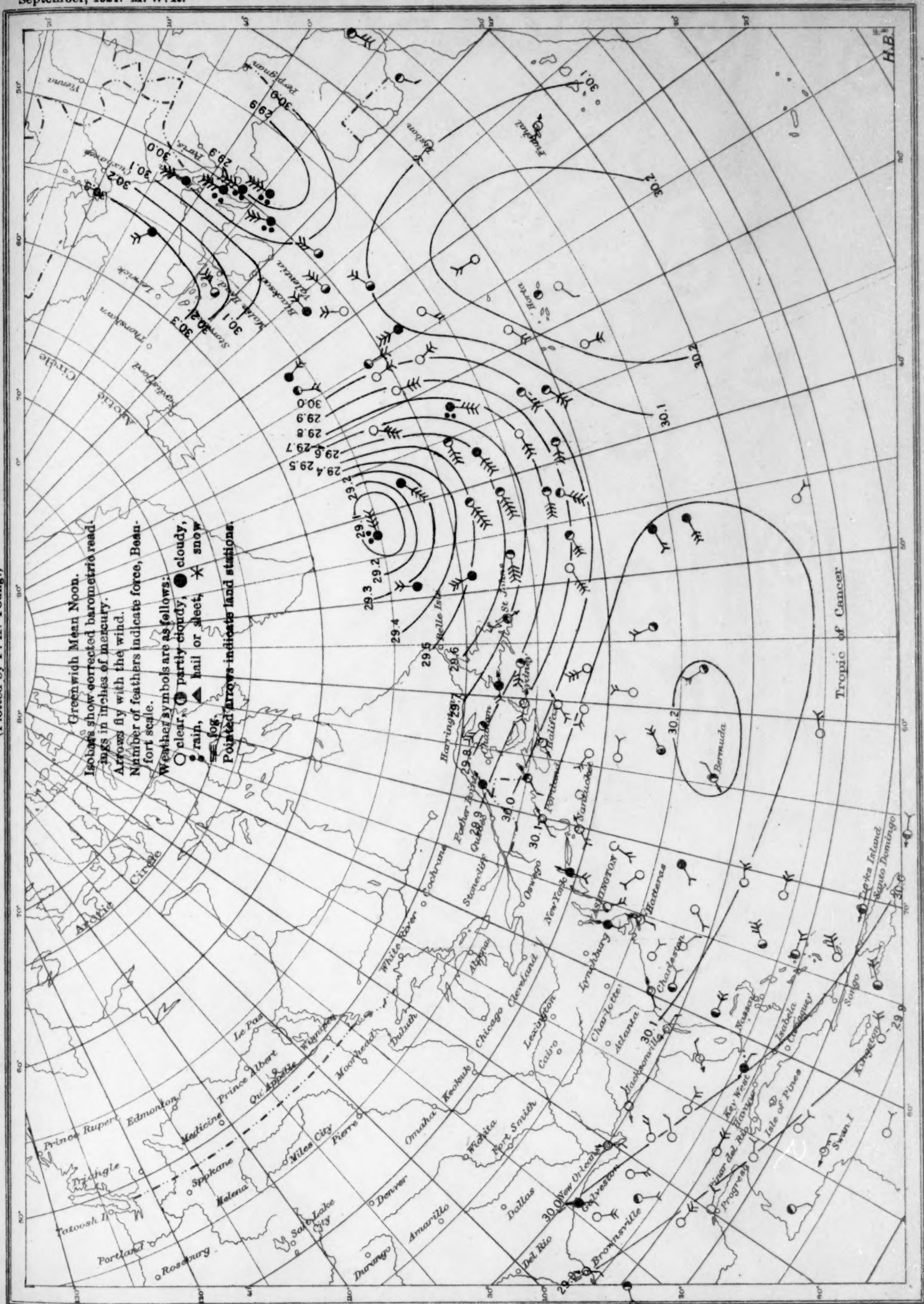
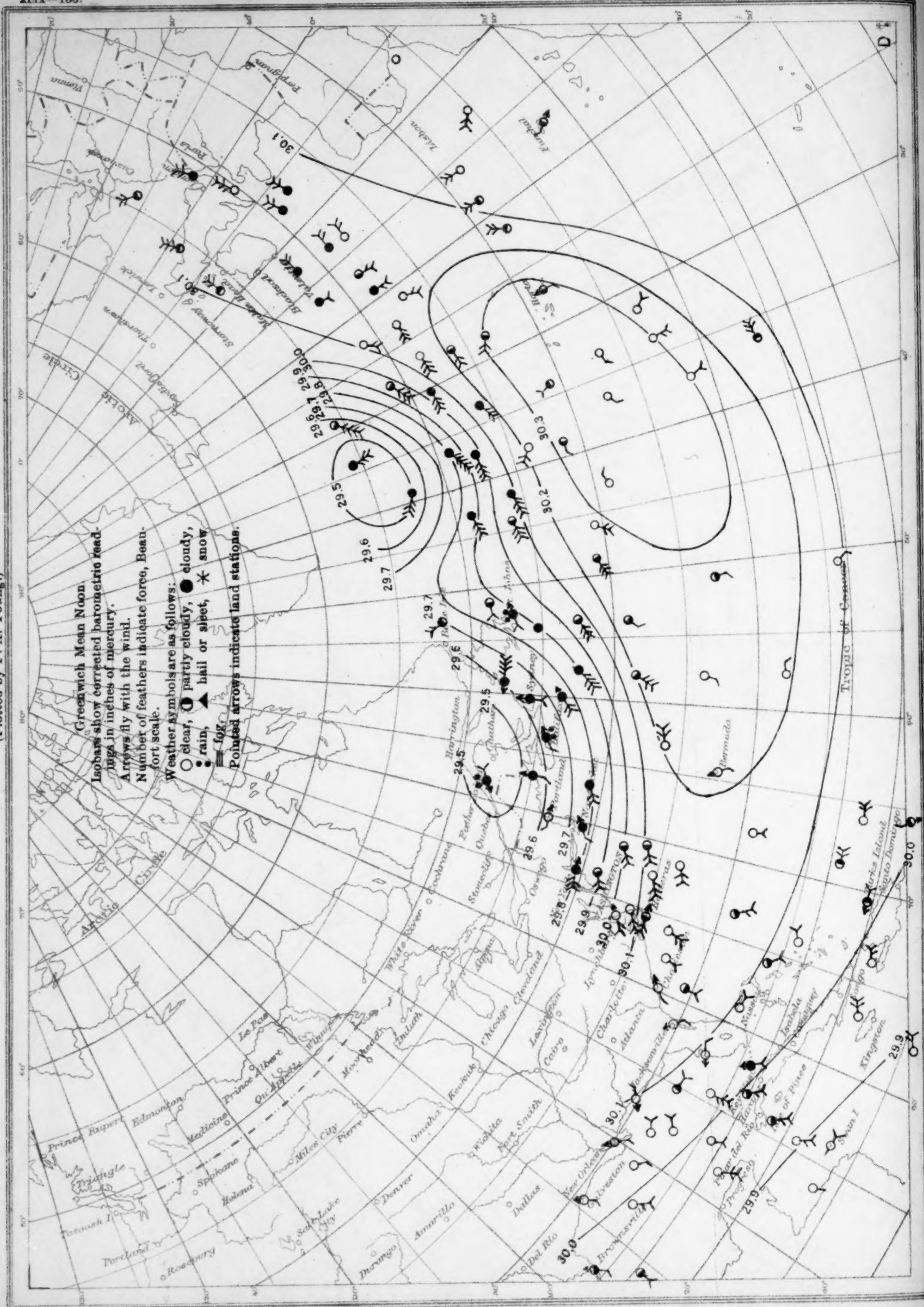


Chart XVI. Weather Map of North Atlantic Ocean, September 18, 1921.  
(Plotted by F. A. Young.)



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# SEPTEMBER, 1921.

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### CORRIGENDA.

#### REVIEW, JANUARY, 1921:

Page 43, Table I, heading "East Gulf States," departure from normal temperature, +0.5 should read +5.1.

#### REVIEW, MARCH, 1921:

Page 174, Table I, heading "Ohio Valley and Tennessee," departure from normal temperature, +1.1 should read +10.5. Likewise under the heading "Lower Lake Region," +1.0 should read +10.1.

#### REVIEW, AUGUST, 1921:

Page 459, first column, sixth row, the corrected value for August 29, recorded "1.996" should read "1.965"; similarly, for August 30, instead of "1.451" read "1.951," and for August 31, instead of "1.925" read "1.942."

† In marine separate.